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THE DEVELOPMENT OF AMERICAN ARMOR-PLATE.

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PREFATORY NOTE.

[It was the original intention of the author to contribute to the Franklin Institute the results of the recent armor-plate trials at Indian Head, in the form of a report. Owing, however, to the unavoidable delay in publishing the contribution, and to the fact that an excellent report of these trials has been published by the Chief of the Bureau of Ordnance of the Navy, such a report would appear unnecessary.

His aim has been, therefore, to prepare a paper giving a brief sketch of the development of armor-plate, together with the more important details of the official report.

The paper has been prepared from the standpoint of the metallurgist, rather than that of the military engineer.

In the works of Very and Orde-Browne we have a complete and excellent history of the development and use of heavy armor-plates for naval and military purposes, but in these works the metallurgical side is but lightly touched upon.

Of course, much might be written upon the methods and appliances used in the manufacture of armor-plate, but such would seem more properly to belong to the province of metallurgy, than to a short paper on the present status of armor-plate in the United States. At the present time great interest is centred upon the use of the complex steel alloys and the methods used to harden them, and it is to these subjects more particularly that the author would call attention.

The detailed methods of producing such alloys as well as the several methods for quenching and tempering armor-plate are naturally kept secret by the steel manufacture.

The results of such operations are, of course, made public at the trials, and the possible deductions to be made therefrom are patent to every observing and thinking engineer.

The fact that the author has had exceptionally good opportunities to make such observations, he feels to be a sufficient excuse for publishing his views in the following paper.]

Sir Thomas Brassey, in his work on *The British Navy*, in speaking of armor and armor experiments,* says: "The defensive armor with which it has been customary of late to protect the heavy ships of modern fleets, may be considered with reference to its thickness, the material of which it is made and the method employed in its manufacture." Though ships' armor has been rarely subjected to the experience of real war, many questions referring to resisting power of the plates composing it have long been experimentally settled. "The general question is entering on a new stage; and there is now a *prima facie* case for inquiry, whether the increased power of armor-piercing guns and the augmented

* London, 1882, vol. ii, p. 3.

thickness of plates, as well as the introduction of new material into its composition, have not created a set of conditions which no longer support previously received theories of penetration and resistance."

These remarks were made in 1882, and now, in 1892, we find that with the introduction of nickel-steel and other alloyed* steels and with special processes for increasing the superficial hardness of armor-plates, the prediction is amply sustained.

One cannot but be impressed with the fact that with nearly every advance in the naval arts, the demands placed upon the metallurgist increase more and more; surely now, more than ever before, the arts of war must advance hand in hand with the arts of peace.

It seems eminently a prerogative of an institution like the Franklin Institute to take an active interest in the efforts which our Government is making to create a modern navy; surely there is no body of technical men in this country that can better appreciate such work or give it more aid.

In the armor-plates tried at Indian Head, October 31st and November 14th, the author ventures to say we have the most complicated metallurgical products ever dealt with by man. How little we know of that mysterious alloy called steel, how much less when it is further complicated by additions of nickel, copper, etc.!

In order that the author's remarks may be more intelligible to persons in civil life, he has deemed it proper to give a short sketch of the history of protecting ships of war by metallic armor. The subject is much more extensive than generally supposed, and its present advanced stage has only been reached by slow degrees and with a vast expenditure of money.

Although a number of schemes for the use of iron plates to protect batteries and ships were devised between the

* I use the word alloyed here in want of a better term; any steel is an alloy of iron and other elements, but it has only been with the introduction of this new class of steels that it has been necessary to use a compound word to indicate their distinctive characteristics. G.

years 1812 and 1855,* it was not until the Crimean war that any practical results were obtained.

During the action at Kinburn the French floating batteries, protected by four and one-half inch iron plates on seventeen inches of wood backing, were repeatedly hulled by the Russian guns, with no other result than the denting of the plates to the extent of one and one-half inches. In 1857, four-inch iron plates and two-inch steel plates, secured by bolts to two feet of oak, were tested at Woolwich with sixty-eight-pounders with unsatisfactory results. At 400

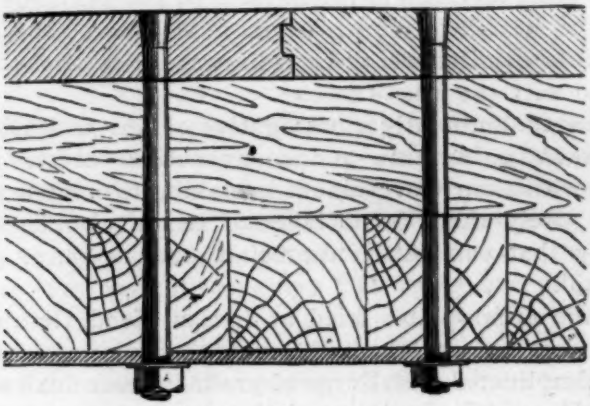

FIG. 1.—*Warrior* target.

yards the plates were badly broken up by both cast and wrought shot.†

In 1861, a target representing a section of the side of the new iron-clad ship *Warrior* (*Fig. 1*), was tried at Shoeburyness with 68-, 100- and 120-pounders, with the result that the plates were more or less cracked, but the ribs and inner skin uninjured. The *Warrior* target was constructed of four and one-half-inch solid iron plates, tongued-and-grooved as shown in *Fig. 1*. The design of the bolts should be noted, as they were vastly better than the system used on some of the earlier American iron-clads.

Ericsson's first battery, the famous *Monitor*, was protected

* See Holley's *Ordnance and Armor*, pp. 623–627.

† *Ibid.*, p. 630.

on the upper hull by six thicknesses of one-inch iron plates with one-half-inch inner skin; the deck by two layers of one-inch iron, and the turret by eight thicknesses of one-inch iron bolted one over the other with overlapping joints. The system of bolting can be fairly well understood from *Fig. 2*,* which was reproduced from a photograph taken shortly after the action with the *Merrimac*. In 1863, a target representing a section of the side of the iron-clad frigate *Bellerophon*, was tried in England. The armor (*Fig. 3*) consisted of six-inch rolled iron plates (not tongued-and-grooved as in the *Warrior* target), bolted to an oak frame with two and

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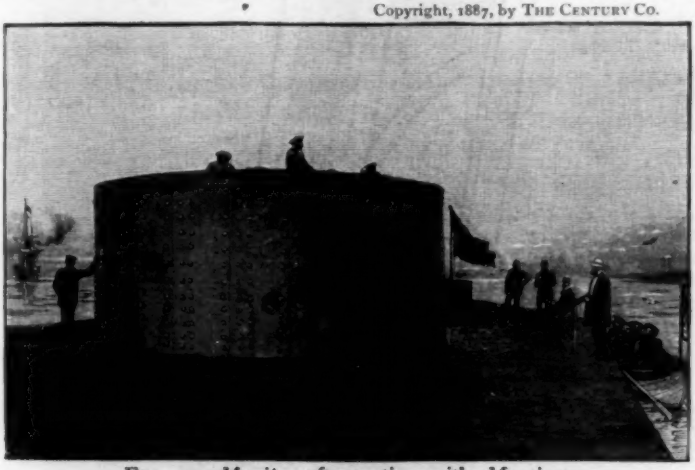

FIG. 2.—*Monitor* after action with *Merrimac*.

one-half and two and three-fourths-inch bolts. Each frame of the target was made of an angle iron 10 x 3½ x ½ inch, and two of 3½ x 3½ x ⅝ inch, riveted together. To the frame thus formed a skin of two thicknesses of three-fourths-inch iron was riveted. On the outside of the skin four horizontal angle-iron stringers were attached, two under the upper armor-plate 9½ x 3½ x ½ inch, the broad flange being square to the skin, and not reaching out to the armor by half an inch. The other two are placed behind the lower plate 10 x 3½ x ½ inch. The breadth of the broader flange being

* The author is indebted to the publishers of *The Century Magazine*, of New York, for the loan of this cut.

the same as the thickness of the backing, it reaches out to and comes in contact with the armor.*

This system made a very material improvement in the structural strength as well as a great addition to its power of resisting projectiles. From this period on, the thickness of iron armor and the wood backing rapidly increased; it seems to have reached its maximum in 1876 in the twenty-two inch iron plates tried at Spezzia during the autumn of that year.

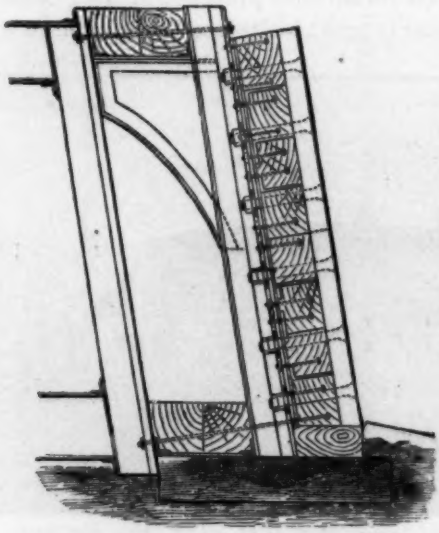

FIG. 3.—*Bellerophon* target.

Up to about 1879, wrought iron in various shapes was almost exclusively used for armor. Browne states that the chief value of wrought-iron plates is due to the fact that they do not transmit the shock to the bolts and adjacent parts of the structure. The blow is absorbed locally. They do not crack much if supported by proper backing, and may be penetrated with comparative ease.

In 1868, what was known as the Hughes hollow stringer (*Fig. 4*) was tried in the construction of the famous Millwall shield. The use of these hollow stringers was estimated by

* Holley, *Ordnance and Armor*, p. 761.

the Russian authorities to be equal to two inches of iron in increasing the defensive capacity. The arrangement of these stringers is shown in *Fig. 4;* they are placed horizontally and riveted to the side of the vessel, the hollow portion being filled with oak or teak.*

The following analyses of Russian and English iron armor-plates have been published by the Russian authorities.†

	Russian Plates.		
	I.	*II.*	*III.*
Carbon, { compound, =	0·07	0·06	0·07
Carbon, { graphitic, =	0·02	—	0·019
Silicon, =	0·12	0·20	0·15
Manganese, =	0·09	0·17	0·03
Phosphorus, =	0·12	0·36	0·04
Sulphur, =	0·02	0·038	trace
Arsenic, =	0·106	0·05	trace
Copper, =	0·02	—	0·07

	English Plates.		
	I.	*II.*	*III.*
Carbon, =	0·04	0·07	0·05
Silicon, =	0·117	0·20	—
Manganese, =	0·09	0·10	0·21
Phosphorus, =	0·165	0·17	0·23
Sulphur, =	0·01	trace	—

It might be well in this place briefly to consider what efforts have been made to use *cast iron* for defensive purposes.

Chilled cast iron is one of the hardest substances known in the arts, but what iron gains in hardness when in this form it loses in other qualities such as elasticity, ductility, etc. In order to possess a maximum of ballistic resistance an armor-plate must be not only very hard, but also elastic and ductile; these fundamental conditions have been thoroughly demonstrated by several trials of chilled cast-iron armor. Two firms in Europe have manufactured armor of this kind

* Hamersley's *Naval Encyclopædia*, 1884, p. 47.

† *Stahl und Eisen*, vol. v, p. 69, *Journal of the Iron and Steel Institute*, No. 1, 1886, pp. 316, 317.

to a considerable extent; Gruson, of Buckau, near Magdeburg, Prussia, and the St. Chamond Company, in France. During the year 1884, a number of armor-plates of chilled cast iron made by Gruson were tried at Buckau. Krupp steel projectiles were used with guns of various calibres. The results of these trials appear to have been considered satisfactory at the time, as were also the similar trials of St. Chamond during April, 1884.*

The result of trials several years later, however, led to both of these firms abandoning cast iron for armor-plate.

It appears from the total results of the trials, that for land defences (glacis armor chiefly), where the conditions were such that the angle of incidence of the projectile was

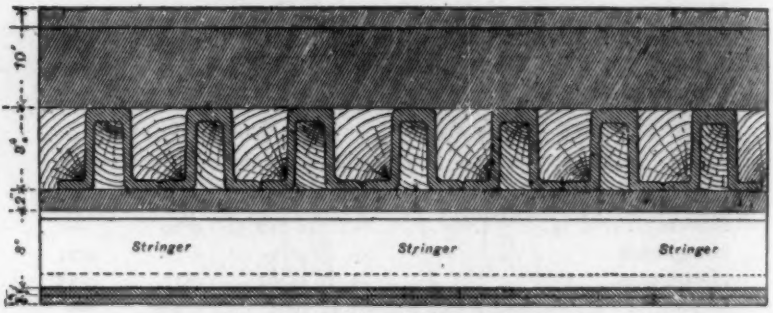

FIG. 4.—Hughes hollow stringer.

not great, chilled cast-iron plates made a good defence. In almost every case the projectiles were broken up.

The penetration was very slight, the surface at the points of impact being chipped off, and, as would be expected, the general destructive effect upon the shield was to crack it in various directions.

When iron is in a crystalline state its tendency to crack under the impact of a projectile is intensified when the latter strikes at a glancing angle, for under these conditions a second blow is delivered by the base of the projectile whilst the molecules of the iron are yet in violent vibration, caused by the impact of the point or ogival.

On the other hand, these plates can be made cheaply and

* *Engineering*, October 17, 1884, p. 374.

of great thickness for land defences, and owing to their hardness, rigidity and the rapidity with which they transmit shocks throughout their entire mass, they must be broken up bodily to be destroyed.

Although this system of armor cannot be considered to have been entirely successful in practice, its peculiarities both as regards construction and the results obtained, deserve more than passing notice.

Gruson's theory appeared to be that as cast iron could be moulded into any desired shape, plates or blocks with a curved profile could be used, which, whilst to a certain extent gaining in efficiency through the power of deflection, gained more by giving to the chilled crystallization a direction such as would put the body of the metal in the best condition for resistance to impact, and give mutual support to the parts of a plate even when the latter was fractured.*

His turrets were made ellipsoidal in shape, so as to make all parts mutually supporting. The ends of each block were slightly hollowed, so that when put in position zinc solder could run into the cavity thus formed by the close-fitting adjacent ends of the blocks, securing them together and thus avoiding all bolts or fastenings of any other description.

What mixture of pig irons Gruson uses to make these castings are not known outside of his works. It produces, however, peculiarly good results.

The fracture is a clear steely-white from the outer surface to about one-quarter of the depth of the casting, changing very gradually to a mottle for one-third farther, the remainder being a fine close-grained dark gray iron. There is no line of demarcation whatever between the chill and the soft iron, the one shading off almost imperceptibly into the other. The structure of the iron throughout appears as fine and close as in Whitworth's fluid-compressed steel, and entirely free from flaws.†

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* Very, p. 532, *Development of Armor for Naval Use. Proceedings of the U. S. Naval Inst.*, vol. ix. No. 3 [1883].

† Very, p. 533.

According to Barnaby,* satisfactory results were not obtained with the use of steel armor until the Spezzia trials of 1876. The plates then tested were 55 cm. (21·5 inches) thick, made at Creusot and such plates were subsequently used by the Italian Government to plate the *Dandolo* and *Duilio*. Three different systems of twenty-two inch armor were then subjected to strictly comparative tests, viz: English and French solid rolled iron plates; sandwiched plating of 10 x 11½ inch iron, interspaced with wood, and one Creusot solid steel plate. The projectiles from a 100-ton (seventeen inch) Armstrong gun completely perforated and broke into fragments the iron plates; it perforated all of the sandwiched plates but failed completely to penetrate the steel one.

When steel for armor was first introduced to any practical extent, it was thought by some authorities that such plates need only be cast, not forged or rolled, but simply quenched in oil and annealed, thus dispensing with all expensive forging operations. This system, however, was soon abandoned for compound or solid forged steel plates. The rivalry between these latter two systems has been keen and active for a number of years, although the solid steel plates made at Creusot have repeatedly shown themselves to be superior to any form of compound armor.

A few years ago, thinking the armor problem about definitely solved by the use of compound armor, the British Government formally adopted it. This led to the expenditure of large sums of money in developing its manufacture in England, which, though active at present, will undoubtedly be discontinued before long.

Before leaving the subject of iron armor, it will be of interest briefly to review some of the metallurgical difficulties overcome in its development. "Between 1854 and 1858 armor-plate manufacture was limited in thickness to four and one-half inches, and but little dependence could be placed in regularity of quality even with this low thickness. The welding was imperfect, the best composition of ores to

* *Trans. of the Institution of Naval Architects*, 1879, p. 29.

produce desired results was not known, steely spots, burned metal, layers of scoria and scale, blow-holes and other imperfections were common and had to be accepted. At first the only rolls available for making armor were such as were used for boiler plates, and these were too light for the requirements. In consequence, the metal was shaped almost entirely under the hammer, which naturally would give results much more irregular than rolling. Time was required to design and erect the proper rolls, so that the real improvement in the condition of armor-plate cannot be said to have commenced much before 1859, and it is about this time that the first real increase in thickness of plates from four and one-half to four and three-fourths inches becomes noticeable."*

In the manufacture of the plates for the first French and English iron-clads much difficulty was experienced.

The worst trouble appears to have arisen from the prevalence of steely spots in the plates, which broke up the tools used in finishing and boring. The inspection was necessarily given wide limits. There was no experience to serve as a guide in this respect, so the manufacture was only carefully watched to gain the necessary knowledge, and the plates were only limited in tests for reception to the indications of specimens. In France, test plates were made of several different mixtures of iron, and were tested for strength in the tensile machine and under the hammer. In this way a standard was established, and the armor was all made of the same mixture. In the process of welding up the packets, the fag-ends were cut off and worked separately. They were then given the pulling and hammer tests to show the fracture, and if they failed to come up to the standard specimen the whole batch of plates was condemned. This was a very crude method of testing armor for reception, but was unavoidable at the start.†

For the sake of convenience we may divide steel armor under three heads, viz: compound, steel and alloyed steel.

* Very, p. 368.

† *Ibid.*, pp. 370, 371.

Compound Armor.—The process of manufacturing what is known as compound armor-plates was first patented in England by Alexander Wilson, of the Cyclops Works (Cammell & Co.), Sheffield, in 1876.*

In 1880, J. H. Ellis, of Sheffield, patented a somewhat similar process which has since been used by Brown & Co., of that place.†

The only difference between the two methods, as the author understands them, is that in the Wilson method a certain amount of low carbon steel ("ingot iron") is first cast on the hot wrought-iron back, and then a third layer of high carbon steel cast upon that, the wrought-iron plate being contained in a suitable cast-iron mould. By the Ellis method the low carbon ("ingot iron") steel plate forms part of the mould, the high carbon steel being cast in a space provided between the wrought-iron back and this plate.

Wilson specifies in his patent that the low carbon steel shall have a tensile strength of from 53,000 to 60,000 pounds per square inch, and that the high carbon steel shall contain from 1·25 to 1·5 per cent. carbon.

Ellis specifies for the low carbon plate 0·8 per cent. carbon and 0·8 per cent. manganese.

The principle in both methods appears to be, that the steel being at a much higher temperature than the iron plate, this excess of heat serves to bring its surface to a welding temperature. It is claimed the carbon in the steel carburizes the iron to a depth of from one-eighth to three-sixteenths of an inch, which, it is further claimed, constitutes an inseparable weld. As a matter of fact, however, the steel face is not always securely welded to the iron, and blisters of varying size occur at the joints. Even under the best conditions the steel face is liable to strip off the back, and where the projectiles penetrate, the holes are larger in the back than in front. This is strikingly illustrated in *Fig. 5*, which shows the Cammell compound plate at the Annapolis

* See British Patents, 4,746-1876; 3,472-1877; 2,130-1882; 15,476-1886; 5,727-1887; 9,392-1888.

† See British Patents, 3,629-1880; 1,051-1882.

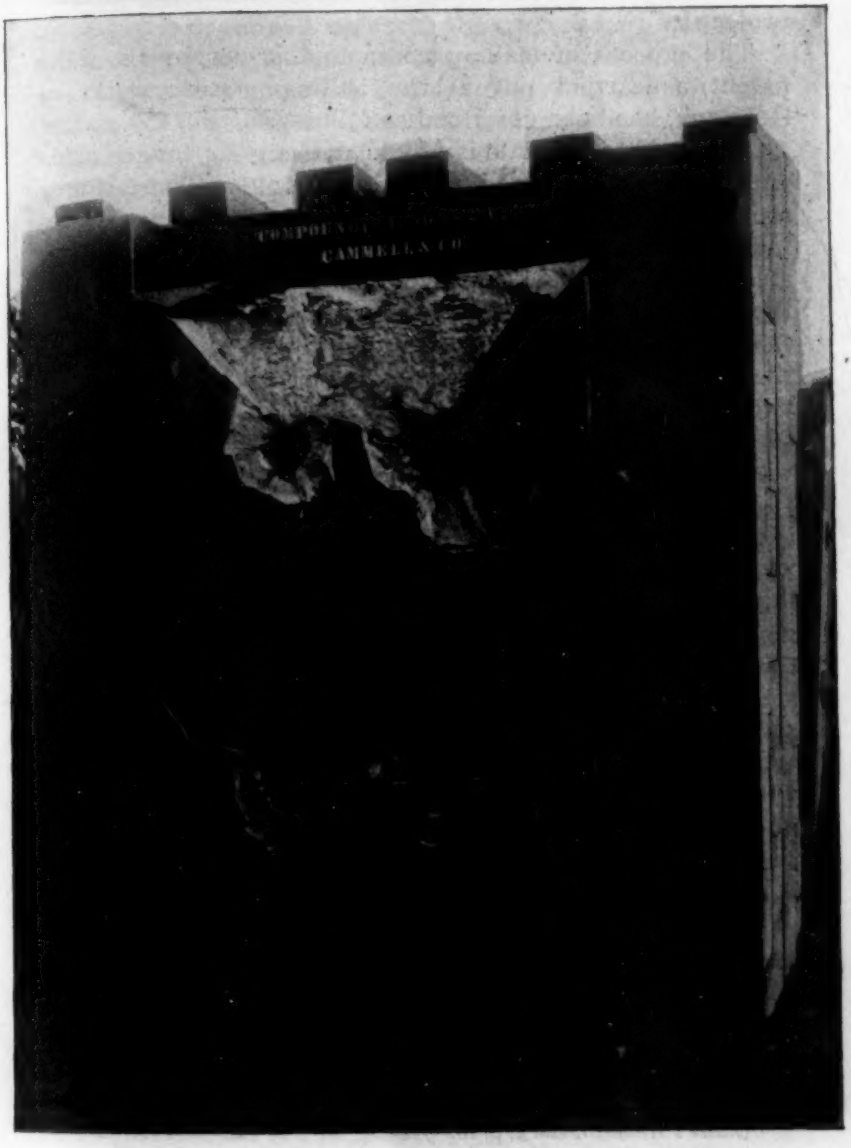

FIG. 5.—Cammell compound plate at Annapolis trials, 1890.

trials of 1890, after the firing of the fourth six-inch Holtzer projectile.

The process of making compound armor by the Ellis patent, as carried out at the Dillingen steel works in Germany, has been described as follows:*

A wrought-iron plate is provided along its longer sides with iron ledges secured to it by steel bolts. These ledges are provided with dovetailed grooves which receive a two-inch covering plate of ·45 per cent. carbon open-hearth steel. This soft steel cover, when rolled down to 0·8 inch in the finished plate, facilitates the subsequent bendings. By this means a five-inch space or mould is provided between the two plates into which the high carbon steel is cast, the two plates or mould being at a bright red heat at the time of the casting. When cool the ledges are removed, the whole reheated and rolled or forged to size.

The margin allowed for carbon in the inner steel stratum is one per cent. above or below standard; for phosphorus, ·025 per cent. provided the carbon is not above the standard, in which case no excess of phosphorus is allowed. Silicon in no case should exceed 0·4 per cent. When tested, a Cammell compound plate of 0·39 per cent. carbon in the steel face, did not prove superior to wrought iron of the same thickness; two others of ·45 and ·48 per cent. carbon were twelve and fifteen per cent. stronger; and a fourth one, with ·56 per cent. carbon gave excellent results. An analysis of one of the best compound English plates was as follows:†

	C.	*Si.*	*Mn.*	*P.*	*S.*	*Cu.*
Layer of steel, ...	·573	·173	·617	·054	·046	·026
Layer of iron, ...	·040	·117	·090	·165	·010	·016

The analyses given by Russian authorities of two similar plates are as follows:‡

							Tensile Strength.		Elongation.	
	C.	*Si.*	*Mn.*	*P.*	*S.*	*Cu.*	*In direction of fibre.*	*Across the fibre.*	*In direction of fibre.*	*Across the fibre.*
Layer of steel, .	0·66	0·10	0·93	0·03	0·05	0·02	93·650 lbs.	88·490 lbs.	1·17%	0·39%
Layer of steel, .	0·62	0·12	0·90	0·20	0·30	0·02	96·200 "	136·500 "	1·9%	1·8 %

* *Glaser's Annalen*, vol. x, p. 16. *Jour. of the Iron and Steel Inst.*, No. 1, 1882, p. 365.

† *Ibid.*, p. 367.

‡ *Stahl und Eisen*, vol. v, p. 133.

At Spezzia, in 1882, the steel faces of Brown's and Cammell's plates contained, respectively, 0·65 and 0·7 per cent., and Creusot steel plate about 0·45 per cent. carbon.*

It seems to the author useless to give any further particulars of the methods of making compound armor, as they are now practically obsolete, and in a few years will be undoubtedly replaced by better methods. In almost every case which has come to his notice within the last two years, compound armor has shown itself inferior to solid steel and alloyed steel plates.

As early as the Spezzia trials of November, 1882, compound plates showed themselves inferior to Schneider's (Creusot) steel plates in certain particulars.

"From an accurate examination of the cracks and the fractured sections, it was observed that in the compound plates the steel, and also the iron, showed rather a coarse grain; distinct strata of the metal imperfectly welded were noticed as well as cavities and traces of scoria. It was also noticed that the thickness of the steel stratum was not uniform, varying from six and one-fourth to four and three-fourths inches. It was noticed that in the weld of the two metals the iron presented a spongy appearance as if of inferior quality.

"In the Schneider plate a very fine grain was observed, uniform and compact, and showing a much greater molecular tenacity."†

It should be noted in this connection that the advantages of compound armor or, in fact, any face-hardened armor are, of course, more prominently demonstrated against oblique than against direct firing.

In most cases of armor-plate trials the gun has every advantage, the plate being subject to conditions which would seldom occur in actual warfare. It is rigidly fixed to a backing, the force of the impact of the projectiles must be

* Capt. Orde Browne, *Journal of the Iron and Steel Inst.*, No. 1, 1884, p. 117.

† Report of the Italian Commission. See Very, *Development of Armor for Naval Use. Proceedings of the U. S. Naval Institute*, vol. ix, No. 3, 1883, p. 502.

absorbed by a very small mass of material as compared with a ship's side, besides there is the absence of a structural flexibility or give, existing in the ship, which is no small factor in absorbing the force of the blow. Under the more recent trial conditions the point of impact is normal to the face of the plate, and the gun so close, that the projectile strikes with practically a muzzle energy.

Steel Armor.—The use of iron armor may be said to have ceased and the advent of steel armor to have taken place with the introduction of the 100-ton gun in 1876. At the celebrated Spezzia trials of that year the solid steel plates made by Schneider & Co., of Creusot, showed themselves superior in many particulars to the wrought-iron and sandwich plates subjected to the same tests. Such steel plates as the author has already mentioned, were subsequently adopted by the Italian Government. From this period up to within the last year or so the contest has been between compound and steel armor, the former being developed to its greatest extent in England and the latter in France.

It was not until about the time of the *Nettle* trials of May 19, 1888, that the English made any serious effort to catch up with the French in the manufacture of steel plates; these trials may therefore be considered as marking the beginning of the steel armor making era in England.

One of the plates then tried was made by Cammell and the other by Vickers. They were 8 x 6 feet x 10½ inches, and weighed 9·4 tons. Three a. p. 100-pound Holtzer and two Palliser chilled iron projectiles were fired at each plate —the range thirty feet and the striking energy 2,723 feet.

Cammell Plate.—Round 1 (Holtzer) penetrated 23·3 inches and broke in two, the head remaining in backing and base in plate.

Round 2 (Holtzer) penetrated 13·1 inches and lodged unbroken. Rounds 3 and 4 (Palliser), projectiles broken up, heads remaining in plate. Penetrations not given. Round 5, centre (Holtzer), penetrated 16 inches, lodged unbroken.

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* *The Year's Naval Progress*, p. 289. Office of *Naval Intelligence* Washington, D. C., July, 1891.

No through cracks at all developed. The plate showed, by the difference in the penetrations of the Holtzer projectiles, a decided lack of uniformity in the metal of which it was composed. The bulging on the back was very pronounced, and on the whole the plate cannot be considered equal to an average Creusot steel plate of the same or even an earlier date.

Vicker's Plate.—Round 1 (Holtzer), penetrated thirteen and one-half inches, and rebounded entire. Round 2 (Holtzer) penetrated thirteen inches and rebounded somewhat distorted. One radial through crack developed. Rounds 3 and 4 (Palliser), penetrations slight and projectiles broken up —no through cracks. Round 5, centre (Holtzer), penetrated thirteen inches and rebounded slightly distorted. One short through crack developed,

The penetrations give an evidence of great homogeneity of the metal. The elasticity of the plate was marked by the rebounding of the projectiles.

The general results were such as to lead to the belief that it was very similar in composition to the Creusot steel plates tried at Spezzia in 1876.

Since 1888 the Schneider (Creusot) steel plates have increased in efficiency, their maximum having probably been reached at the Annapolis and Ochta trials in 1890.* Some little progress seems also to have been made in England in the production of steel plates, Messrs. Vickers having received as a result of the *Nettle* trials, a large order from the Admiralty. The day of the steel plate, however, is past, as it will undoubtedly be superseded by the alloyed steel plate.

Lieut. Southerland, U.S.N., in his able review of "The Armor Question in 1891,"† very sensibly says: "The value of steel for armor protection can best be demonstrated by comparing it with the compound metal. With steel plates the face is hardened, but not to the same degree as the face of the compound. This disadvantage, however, even in plates of medium thickness, is more than compensated for

* *The Year's Naval Progress*, 1891, pp. 300 to 328.

† *Ibid.*, p. 332.

by the relatively greater hardness of the back, which tells more and more in favor of the steel as the plates increase in thickness.

"As a result of the softer face, projectiles of medium quality, although broken up by both metals, obtain a greater penetration in steel than in compound, as is evidenced by the French trials, but with a. p. (armor-piercing) projectiles, the resistance of the steel depending on its mass, penetration is less than in compound, where the hard face once overcome, the resistance of the soft back to penetration is but slight."

To the unprejudiced mind the advantages of steel over compound armor are manifest. It is not only more homogeneous than compound, but has the great advantage of being able to be cast into shapes which compound cannot.

As a result of the experiments of the Gavre Commission steel armor was found to possess a superior degree of toughness and elasticity. This property tends to distribute the projectile energy imparted to the plate more uniformly throughout its mass, thus decreasing its tendency to crack and break up, even though the projectile may attain a greater penetration than in the case of a compound plate.

The great inherent defect of solid steel armor-plate is the liability to through cracking. "If this through cracking causes the falling off of the fractured parts, either from succeeding shots or from the motion of the vessel in a seaway, steel would be useless for armor protection; but a careful study of armor trials is conclusive in showing that the system of bolting employed will hold fractured parts in place, unless the plate is excessively fractured by a greater number of blows than one can conceive of its receiving."*

A noticeable feature in steel plates is their tendency to form serrated cracks, as compared with the straight or curved lines of cracks in the compound. This enables fractured parts to dovetail into each other so as to cause them to remain in place, even when unsupported by

* *The Year's Naval Progress.* Office of *Naval Intelligence*, Washington, D.C., July, 1891, p. 332.

surrounding plates. It is evident that when badly cracked, the separated parts of steel plates will still offer considerable resistance to penetration. In the recent Annapolis trials, at the end of the fifth round of shots, each of the four separate parts of the cracked steel plate would still have resisted another projectile, while the compound plate, which presented a thickness of less than seven inches of wrought iron, would have been open to perforation by projectiles from as small a rapid-fire gun as the Hotchkiss fourteen pounder.

About the year 1887, one of the best British authorities, in speaking of steel armor, states that "Creusot steel is not usually as hard as the steel used in the face plates of compound armor, and is as a mass more rigid."†

"As compared with compound, steel armor admits the point of the shot at first with less resistance, but it does not yield at the point of impact even where badly backed, and is therefore less dependent on backing than compound armor. As the shot enters, it wedges and heaps up the metal around it, the plate coming forward and swelling at the point of impact and yielding by radiating cracks. It may be questioned if a case could be found of a concentric crack being made in steel armor. Nearly all cracks made extend through the metal, but by the employment of a large number of bolts the fragments may be held up, and considerable resisting power maintained after fracture. On the other hand very soft steel plates admit of perforation, and in their character resemble wrought iron more or less."‡

The action of the shot in wedging and heaping up the metal is much the same with nickel-steel plates—which in fact can only be regarded as steel plates strengthened and toughened by the addition of nickel.

Browne states§ that "steel plates are uncertain in their behavior and are liable to spontaneous fracture after tem-

* *The Year's Naval Progress*, 1891, p. 333.

† C. Orde Browne, *Armor and its Attack by Artillery*, part II, p. 85, London, 1887.

‡ *Ibid.*, part II, p. 85.

§ *Ibid.*, part II, p. 99.

pering or after annealing." If such was the case eight or ten years ago, it was doubtless due to a want of knowledge and experience in the manufacture of such large masses of steel. This difficulty has probably been overcome, as we seldom hear of plates cracking spontaneously unless they have been unduly strained.

[*To be continued.*]

THE WORLD'S FAIR.

The World's Columbian exposition, at Chicago, will open on May 1, 1893. The following data give the reader an idea of its scope and magnitude and of its present status and prospects.

The Exposition is under the auspices of the United States Government. Its participants include not only the United States Government and the forty-four States and five Territories of the American Union, but also nearly every foreign government. Its international character is assured.

The foreign nations and colonies which thus far have determined to participate in the exposition, and the amounts of their appropriations, made or officially proposed, as far as information concerning them has been received at headquarters, are the following:

Argentine Republic,	$100,000	British Honduras,	$7,500
Austria,	149,160	Cape Colony,	25,000
Belgium,		Ceylon,	40,000
Bolivia,	100,000	India,	
Brazil,	600,000	Jamaica,	20,000
China,		Malta,	
Chile,	100,000	Mashonaland,	
Colombia,	100,000	New South Wales,	
Costa Rica,	100,000	New Zealand,	
Denmark,		Queensland,	
Danish West Indies,		South Australia,	
Ecuador,	125,000	Tasmania,	
Egypt (informal),		Trinidad,	15,000
France,	400,000	Victoria,	
Algeria,		West Australia,	
Germany,	214,200	Guatemala,	120,000
Great Britain,	125,000	Hawaii,	
Barbadoes,	6,000	Hayti,	
British Columbia,		Honduras,	20,000
Bri ish Guiana,	25,000	Italy (informal),	

Erythria,		Salvador,	$12,000
Japan,	$630,675	San Domingo,	
Korea,		Siam,	
Madagascar,		Spain,	
Mexico,	750,000	Cuba,	25,000
Netherlands (informal),		Transvaal,	
Dutch Guiana,	10,000	Turkey,	
Dutch West Indies,	5,000	Uruguay,	
Nicaragua,	30,000	Venezuela,	
Orange Free State,		Total,	$4,004,565
Paraguay,	25,000		
Persia,			
Peru,	125,000	Thirty-nine nations.	
Russia,		Twenty-four colonies.	

Bolivia appropriated $10,000 for preliminary expenses, and authorized its President to draw on the regular diplomatic appropriation for any further sum needed, the whole amount estimated to be necessary being $100,000. Of Ecuador's $115,000, the city of Guayaquil furnishes $25,000. Paraguay has authorized its President to spend whatever sum may be necessary to have the country creditably represented. It is reported that $25,000 of expenditure is contemplated. Mexico has voted $50,000 for preliminary expenses. No doubt is felt that the balance of the $750,000 proposed will be forthcoming. It is assured that quite a number of the appropriations named above will be increased.

From information received at Exposition headquarters, it can be said to be almost assured that there will soon be added to the above list Norway and Sweden, Hungary, Switzerland, Canada and several others. At a low estimate the total of the appropriations of foreign nations will reach $5,000,000. Nearly all of the participating nations will erect buildings in the exposition grounds. Building sites have already been selected for Great Britain, Germany, Japan, Turkey, Mexico, Peru, Brazil, Ecuador, Colombia, Costa Rica, Guatemala and Chile. The buildings of foreign nations will present most varied contrasts in respect to size, architecture and adornment.

The United States Government has appropriated thus far $1,500,000, of which $400,000 was set apart for its building and $250,000, approximately, has been drawn for the cost of five sessions of the National Commission, two ses-

sions of the Board of Lady Managers, the salaries of the officers and employés of these two bodies, and the expenses of three special agents of the Treasury Department who were sent to Europe to explain to foreign commissions and governments the regulations of the department governing the importation of exhibits. A considerable portion of the remainder has been spent in preparation of the Government exhibit by the Board having the matter in charge. The Congress now in session is expected to appropriate a sum sufficient for the future expenses of the National Commission and Lady Managers, and the continued preparation of the Government exhibit, and also about $700,000 for the exposition awards and the payment of the awarding juries, as obligated by the Act of Congress creating the National Commission. The Government, as elsewhere stated, has been asked, also, to appropriate something for a District of Columbia exhibit, and $5,000,000 in general aid of the exposition.

Twenty-six States and two Territories, thus far, have made appropriations for their representation at the exposition, as follows:

Arizona,	$30,000	New Hampshire,	$25,000
California,	300,000	New Jersey,	20,000
Colorado,	100,000	New Mexico,	25,000
Delaware,	10,000	North Carolina,	25,000
Idaho,	20,000	North Dakota,	25,000
Illinois,	800,000	Ohio,	100,000
Indiana,	75,000	Pennsylvania,	300,000
Iowa,	50,000	Rhode Island,	25,000
Maine,	40,000	Vermont,	15,000
Massachusetts,	75,000	Washington,	100,000
Michigan,	100,000	West Virginia,	40,000
Minnesota,	50,000	Wisconsin,	65,000
Missouri,	150,000	Wyoming,	30,000
Montana,	50,000		
Nebraska,	50,000	Total,	$2,695,000

In several of these States the appropriations made are only preliminary, and will be largely increased. In Iowa, for example, the Executive Committee of the State Commission has prepared estimates aggregating $339,000, and will ask the Legislature to appropriate accordingly. Colorado, Maine, Massachusetts, Minnesota, New Jersey and West Virginia promise increased appropriations. In Colorado,

an additional $50,000, approximately, has been voted by the counties, and in Indiana about $10,000 has been raised by school pupils and teachers. In California, too, some of the counties are supplementing the State appropriation.

Nine States which, owing to constitutional restriction, or other prohibitive reason, made no World's Fair appropriation, have held State conventions and formed organizations of the stock-subscription sort for raising the amounts deemed necessary for creditable representation. These States, and the sums they are thus raising, are:

Alabama,	$50,000	Oregon,	$100,000
Arkansas,	100,000	South Dakota,	80,000
Florida,	100,000	Tennessee,	100,000
Georgia,	100,000	Texas,	300,000
Kansas,	100,000	Total,	$1,030,000

The legislatures of several States which have made no provision for representation are now in session, or soon will be. In Maryland, a bill for $100,000 is pending. In New York, a bill for $250,000 has been introduced, and a second bill for $500,000 is advocated by several influential organizations, which believe that sum necessary for creditable representation. Nearly all of the States and Territories that have not already made liberal appropriations, are expected to do so in time. It is reported that the Government will be asked to appropriate $50,000 for the representation of the District of Columbia, and perhaps something for an Alaska exhibit. The aggregate expenditure by the States and Territories is expected to reach $5,000,000.

Information concerning the State Buildings is yet quite incomplete, as but few of the plans have been approved. It is expected that nearly all will erect buildings as State headquarters and receptacles for collective exhibits illustrating their resources. Thus far, data for the buildings of twenty-two States, as projected, have been received at headquarters. These structures, for the most part, will be two stories in height; will average about 50 x 75 feet in dimensions, and will cost from $10,000 to $100,000 each.

The size and cost of the great exposition buildings are indicated in the following table:

Buildings.	Dimensions in Feet.	Area in Acres.	Cost.
Manufactures and Liberal Arts,	787 × 1687	30·5	$1,500,000
Administration,	262 × 262	1·6	435,000
Mines,	350 × 700	5·6	265,000
Electricity,	345 × 690	5·5	401,000
Transportation,	256 × 962	5·6	370,000
Transportation, Annex,	425 × 900	8·8	
Woman's,	199 × 388	1·8	138,000
Art Galleries,	320 × 500	3·7	670,000
Art Galleries, Annexes (2),	120 × 200	1·1	
Fisheries,	165 × 365	1·4	224,000
Fisheries, Annexes (2),	135 diameter.	·8	
Horticulture,	250 × 998	5·7	302,000
Horticulture, Green-houses (8),	24 × 100	·5	25,000
Machinery,	492 × 846	9·6	1,200,000
Machinery, Annex,	490 × 550	6·2	
Machinery, Power-house,	100 × 461	2·1	85,000
Machinery, Pumping Works,	77 × 84		
Machinery, Machine Shop,	146 × 250		
Agriculture,	500 × 800	9·2	618,000
Agriculture, Annex,	300 × 550	3·8	
Agriculture, Assembly Hall, etc.,	125 × 450	1·3	100,000
Forestry,	208 × 528	2·5	100,000
Saw Mill,	125 × 300	·9	35,000
Dairy,	100 × 200	·5	30,000
Live Stock (3),	65 × 200	·9	335,000
Live Stock, Pavilion,	280 × 440	2·8	
Live Stock, Sheds,	—	40·7	
Casino,	120 × 250	·7	210,000*
Music Hall,	120 × 250	·7	
		153·8	$7,041,000
U. S. Government,	345 × 415	3·3	400,000
U. S. Government, Imitation Battle-ship,	69·25 × 348	·3	100,000
Illinois State,	160 × 450	1·7	250,000
Illinois State, Wings (2),	—	·3	
		159·4	$7,791,000

* Including connecting peristyle.

The last three are being erected, the first two by the United States Government, and the third by the State of Illinois. The visitor, however, will naturally class them among the great exposition structures.

The exposition buildings, not including those of the Government and Illinois, have also a total gallery area of 45·9 acres, thus making their total floor space 199·7 acres. The Fine Arts building has 7,885 lineal feet, or 145,852 square feet of wall space.

All of the annexes will be scarcely less imposing and architecturally beautiful than the main buildings themselves. The live-stock sheds, which will cover an immense area as indicated, are to be constructed as inexpensively as possible without marring the general architectural effect. The power-houses, pumping works, etc., are to be exhibits in themselves, and so constructed as to be readily inspected by visitors. There will be several exposition buildings in addition to those named, but data concerning them are not yet fully determined. Among them will be a Press building, in which every possible convenience and accommodation for the press representatives of the world will be provided; and a reproduction of the Spanish convent, "La Rabida," in which a wonderfully complete collection of Columbus relics and allied exhibits will be gathered. The total cost of the exposition structures alone is estimated at $8,000,000.

The amount ($8,000,000) which the Exposition Company expects to expend upon buildings represents less than one-half of its total estimated expenditure for the great enterprise. Following are estimates of various other expenses prepared by the Ground and Buildings Committee:

Grading and filling, etc.,	$450,400
Landscape and gardening,	323,490
Viaducts and bridges,	125,000
Piers,	70,000
Waterway improvements,	225,000
Railways,	500,000
Steam plant,	800,000
Electricity,	1,500,000
Statuary on buildings,	100,000
Vases, lamps and posts,	50,000
Seating,	8,000
Water supply, sewerage, etc.,	600,000
Improvements of lake front,	200,000

World's Congress Auxiliary,	$200,000
Construction department expenses, fuel, etc.,	520,000
Organization and administration,	3,308,563
Operating expenses during Exposition,	1,550,000
	$10,530,453

Add to this the amount estimated to be necessary for buildings ($8,000,000), and the grand total sum to be expended by the Exposition Company stands at $18,530,453. This does not include, of course, the expenditure by the United States Government, the States of the Union, or foreign countries. Of this $18,530,453, about $17,000,000 must be paid out before the gates of the Exposition are thrown open to the public, on May 1, 1893. The total amount which the Exposition Company has paid out up to date, for all purposes, is $2,779,707. Owing to the present enormous demands of construction, the expenditure is now running at nearly $1,000,000 a month.

In view of the showing given above, a statement of the Exposition's resources will be found interesting in this connection.

RESOURCES.

Stock subscriptions,	$5,721,230
City of Chicago bonds,	5,000,000
Prospective gate receipts,	10,000,000
Concessions and privileges,	1,500,000
Salvage,	1,500,000
Interest on deposits,	33,452
Total,	$23,754,682

To the resources will be added future interest on bank deposits and future subscriptions to stock. New subscriptions are coming in daily, and the amount which will thus be realized is certain to be large, though how much it will be can now only be surmised. An increase of $200,000 from these sources is a safe estimate. On the other hand, some deduction must be made for delinquency in the payment of subscriptions to stock. Thus far, sixty per cent. of the subscribed amounts has been called for, and $3,433,800, or more than sixty per cent. has been actually paid in, quite a number of subscribers having voluntarily paid up in full without waiting for the successive calls. The subscribers number about 30,000. Among subscribers there have been nearly 500 deaths, and this, together with impoverishment,

etc., has caused thus far a delinquency in collections of between seven and eight per cent. of the amount due. This is less than was anticipated. Making a very liberal allowance for delinquencies, the net resources, as estimated, stand in round numbers at $23,350,000, or about $4,825,000 in excess of the total estimated necessary expenditure.

But of the resources the gate receipts, concessions and privileges, and salvage, representing a total of $13,000,000, are not only estimates but are necessarily prospective. They cannot be realized even in part until the exposition opens and is in progress. The salvage from the disposal of the buildings cannot, of course, be realized until after the fair closes. It follows that the resources available previous to the opening of the exposition, by which time, as explained above, $17,000,000, approximately, must be expended, are cut down to about $10,750,000. It will be seen that about $6,250,000 must be provided for in some manner. Accordingly, the United States Government may be asked to aid the exposition by taking a financial interest in it to the extent of $5,000,000. In view of the fact that the National Commission, representing the Government, in adopting the classification of exhibits, made the scope of the exposition so extensive that, as the Exposition Directory has found, it could not possibly be creditably fulfilled within the expenditure of the $10,000,000 which was at first deemed sufficient—and which Chicago has provided, according to promise—it is believed that Congress will consider it incumbent upon the Government, both in point of actual obligation and that the national honor may be maintained before the world, to provide the means for meeting the excess of expenditure which the action of its representative rendered necessary. With such assistance, to the extent of $5,000,000, the Exposition Company believes it will be able to meet all demands.

The actual erection of the exposition buildings began in June, 1891. Now all of them are being pushed rapidly towards completion. Already several are under roof. About 4,000 workmen are employed. Work proceeds day and night.

Woman's Building.—This is farthest advanced of all. It is roofed and almost completed exteriorly. Covered and adorned with "staff," it appears like a marble palace. The furnishing of the interior is proceeding.

Mines Building.—The framework is up, and finishing touches are being put on the iron and glass roof. The "staff" is being applied.

Electricity.—Framework completed up to gallery floor, and nearly all of the great steel trusses for the roof in place.

Horticulture.—The pavilions are up to the roof line. The west portion is roofed and windows are being placed. The iron work of the dome is being put in position.

Transportation.— Framework practically completed, as also roof sheathing over galleries. Clere-story trusses are being raised.

Administration.—Structural work of the four pavilions completed and exterior covering being applied. Iron work in place up to base of dome, 170 feet from ground.

Machinery Hall.—Floor and 6,000 supporting piers completed; superstructure going up, and foundation for annex being laid.

Agriculture.—Interior columns and gallery girders and joists in position, and the great iron columns supporting the roof being placed. Of the 7,000,000 feet of lumber which the building will contain, more than half is already utilized.

Manufactures and Liberal Arts.—The thirty and one-half acres of flooring are laid, and the superstructure is begun. The huge steel trusses for the roof, which together will contain more metal, by fifty per cent., than the Brooklyn bridge, will soon be raised.

Art Galleries.—Basement and floor are completed, and the brick walls have reached an average height of ten feet above the second floor. More than 5,000,000 brick are already laid.

Fisheries.—The gallery trusses of the main building are placed, and the iron framework of both pavilions is completed.

Forestry.—This is about three-fourths finished, and will be occupied by the model makers until spring, when the outside rustic work will be put on, and the temporary roof will be replaced by a thatched one.

Dairy.—All the columns are up to the roof line, and the gallery floor is being laid.

Work on the Illinois State building and on the United States Government building is being pushed rapidly. The imitation battle-ship is completed to the deck level.

Insurance is placed and increased on the buildings as their construction proceeds. The amount now carried is above $1,000,000. During the exposition, it is estimated not less than $150,000,000 or $200,000,000 of insurance will be carried on the buildings and exhibits.

All possible precautions are taken against fire. The exposition grounds are already provided with a full equipment of fire engines and apparatus.

In the construction of the buildings about 60,000,000 feet of lumber and 18,000 tons of steel and iron will be used. In their adornment will be utilized nearly 84,000 pieces of ornamental "staff" work, of which about one-third are already completed.

To supply the exposition buildings and grounds with water two plants are being put in, one with capacity of 24,000,000 gallons a day, and the other of 40,000,000 gallons. Thus 64,000,000 gallons a day will be available. The pumping works and all of the great machinery furnishing power to the exposition will be open to the inspection of visitors.

A system for drainage, believed to be adequate and perfect, has been adopted. Perfect sewerage, too, is planned. All refuse from the *cafés* and kitchens, and from the lavatories and closets, of which 6,500 will be constructed at an expense of some $450,000, will be received by injectors, and forced by compressed air through underground pipes into four huge tanks, where it will be treated chemically and rendered entirely inoffensive. Work upon these systems is progressing.

Plans adopted for lighting the buildings and grounds

provide for 138,218 electric lamps, of which 6,766 are to be arc lamps of 2,000 candle-power each, and 131,452 incandescent, sixteen candle-power each. The electric lighting will cost something like $1,500,000 and will be ten times as extensive as was employed at the Paris exposition. The light and motive plant at the exposition, it is estimated, will require 26,000 horse-power, of which 22,000 will be required for the electric plant.

Transportation to and from the exposition, both for visitors and exhibits, will be as perfect as it is possible to make it, both in the matter of facilities and rates. Greatly reduced rates on all railroads and some of the steamship lines will prevail. Definite arrangements are yet to be perfected. Much attention is being given to the question of furnishing abundant facilities for reaching the grounds from all parts of Chicago, and it can be asserted that existing means, already extensive, will be increased so that a maximum of 400,000 a day can be carried to and from the grounds. For the transportation of exhibits, arrangements have already been made with nearly 500 railway and steamship lines, including all of the trunk railroads and more important lines in the United States. Of these transportation lines, 417 have agreed to charge regular tariff rates on exhibits to the exposition, and to return them to starting points free of charge, provided their ownership remains unchanged. Thirty-seven have agreed to charge half regular rates both ways, and thirty-three have promised to transport them free both to and from the exposition. The Atlantic Transport Line of Steamers, which runs freight steamships between London and New York, Philadelphia and Baltimore, will make no charge on exhibits in either direction, except on such as, owing to their excessive size or weight, require extra help in their handling. In such cases only the expense of the extra help will be charged. Foreign exhibits will be admitted free of all duty. Such exhibits, however, if sold in this country, will be subject to payment of regular customs duties.

The World's Congress Auxiliary.—This is organized to provide for the presentation, by papers, addresses and discussion,

of the mental and moral status and achievements of the human race. Under its auspices, a series of congresses will be held in Chicago during the progress of the exposition, in which, it is already assured, will participate a great many of the ablest living representatives in the various fields of intellectual effort and moral endeavor. The Auxiliary embraces between fifteen and twenty main departments, such as Literature, Government, Education, Music, Science, Art, Engineering, etc., in each of which are subdivisions. A programme is being arranged for congresses in each of these departments and divisions, in which specialists and advanced thinkers may participate in discussing the vital and important questions, and presenting the best and latest achievements of the human mind in each. During the exposition the Auxiliary will have the use of a magnificent permanent Art Palace, which the Chicago Art Institute, aided by the Exposition Directory, is about erecting on the lake front. This will have two large audience rooms, each of 3,500 capacity, and from twenty to thirty smaller rooms, of capacity ranging from 300 to 750. The great auditorium will also be utilized for the larger congresses, and numerous other halls are available when required. Each congress will be supervised by a committee of persons actively interested in its particular field, acceptance of such responsibility having already been given. The prospects are that fully 100 congresses altogether will be held. It is the intention to publish their proceedings in enduring form. Detailed information concerning the Auxiliary, or any of its departments or divisions, can be obtained of its President, Charles C. Bonney.

The participation of women in the exposition promises to be one of its most interesting as well as novel features. With a commodious and imposing building, designed by a young lady architect, and with an abundance of money, and with full recognition, indorsement, and aid by the United States Government and the Exposition Directory, the women have an opportunity of showing, in most signal manner, the condition of their sex throughout the world; what are the achievements of woman in the various branches

of human endeavor, and what is her adaptability to different occupations and lines of industrial and charitable work. Under the direction of the Board's President—Mrs. Potter Palmer—the work of organization, and of enlisting the interest of women throughout the United States and in foreign countries, has progressed to a most satisfactory stage.

Jackson Park and Midway Plaisance—the Exposition site—are in the southeastern part of Chicago, and embrace 664 acres, with a frontage of about a mile and a half on Lake Michigan. Forty-five miles of boulevard connect the site with the general park system of Chicago, which embraces fifteen or more parks, aggregating 2,000 acres.

Half a million dollars has already been expended in grading Jackson Park and dredging extensive waterways throughout it. Hundreds of thousands are yet to be spent for landscape gardening, fountains, statuary, pleasure boats, etc. A number of observation towers, from which excellent views of the buildings and grounds can be obtained, will be erected in different parts of the Park.

According to present plans fully 150 restaurants and *cafés* will be in operation in the various buildings and about the grounds. These will be conveniently distributed, and will have an estimated aggregate seating capacity of 6,000 or 8,000.

Midway Plaisance, connecting Jackson Park with Washington Park, will be occupied throughout its entire length by special Exposition features largely of a foreign character, such as the "Bazaar of All Nations," "Street in Cairo," "Street in Constantinople," "Moorish Palace," "Maori Village," etc., to which concessions have been granted, and which, in their production, will represent the expenditure of hundreds of thousands of dollars. Panoramas, cycloramas, the sliding railway, etc., will also be located there.

A single entrance fee, probably fifty cents, will entitle visitors to see the entire exposition proper. The special attractions on Midway Plaisance will make a moderate additional charge.

The hotel accommodations of Chicago, already very

extensive, are being augmented by the erection of fully twenty new hotels, some of which are very large. Two million dollars or more are to be spent by the city and the Park Commissioners, in putting the streets, parks, etc., in presentable condition against the influx of visitors.

It may be said to be assured that the exhibits at the exposition will cover a wider range and be far more numerous than were ever before gathered together. They will present a picture of the condition and industrial progress of mankind in every quarter of the world, and of its achievements in every branch of the sciences and arts. The exposition classification embraces twelve departments, 176 groups, and 967 classes. The application for space by intending exhibitors in the United States alone, numbered 2,082 on January 1st. The number at the Philadelphia Centennial on corresponding date was 864. Applications from foreign exhibitors are reported very numerous and rapidly increasing. It seems assured that the exhibitors will outnumber those at any previous world's fair. The allotment of space will be made about June. The reception of exhibits will begin November 1, 1892, and continue until April 10, 1893. No charge will be made for space for exhibits.

The exposition buildings, as required by Act of Congress, will be dedicated "with appropriate ceremonies" on October 12, 1892, the 400th anniversary of the discovery of America by Columbus. The exercises will occupy three days, beginning on the 11th and closing on the 13th with a grand dedication ball. The committee having the matter in charge has planned to make the ceremonies most impressive in character. Something like $300,000 will be spent to secure this end. The President of the United States and his Cabinet, the Senate and House of Representatives, the Governors of the several States with their staffs, and representatives of all foreign nations will be invited to be present. The mobilization of 10,000 militia and several thousand regulars is planned, as is also an imposing civic and industrial display. In the evenings there will be a magnificent display of fireworks, and in the Park waterways a pageant

of symbolical floats, representing the "Procession of the Centuries." In the dedicatory exercises on the 12th, the complete buildings will be tendered by the President of the Exposition to the National Commission. President T. W. Palmer will accept them on behalf of that body and will at once present them to the President of the United States, who will fittingly respond. The dedicatory oration will follow. Much attention is being given to the musical portion of the programme. This will include a dedicatory ode and orchestra marches written for the occasion. These and other numbers, including "America" and "Star Spangled Banner," will be rendered with full choral and orchestral accompaniment.

In April, 1893, a grand international naval review, preliminary to the opening of the exposition, as provided for by Act of Congress, will be held in New York harbor. Arrangements for this are now being made.

The exposition will open its doors to the public on May 1, 1893, and close them on October 30th, of the same year.

A PRACTICAL CONSIDERATION OF COMPRESSED AIR.

By Wm. L. Saunders, C.E.

[*A lecture delivered before the Franklin Institute, December 11, 1891.*]

In an address recently delivered before this Institute and published in the *Journal* for July, 1891, Dr. Coleman Sellers, in referring to the utilization of the power at Niagara Falls, used the following words:

"You may wonder why compressed air is thought of at all for transmission, as you have known in America that it has been thought to be a very wasteful manner of transmitting power, but the recent improvements that have been made in compressors have very much changed the condition of that mode of transmission, and the fact that so much gain is possible by reheating the air indicates a cheap power which can be transmitted long distances with economy."

This concise and truthful statement has been selected as a text for what I have to say on the subject of compressed air, because, in the first place, it calls attention to the very general impression which exists in America as to the "very wasteful manner," by which power is transmitted by compressed air, and it suggests the true solution of the problem, which is in the direction of improvements in air compressors and reheating the air.

Compressed air, though one of the oldest of the sciences, is in its development and use one of the youngest. Hero of Alexandria, a century before Christ, experimented and wrote upon "Pneumatics," calling special attention to the influence of heat in expanding and contracting air, and Prof. Thurston has given us an account of an invention which was put into practical use by Hero, by which the opening and closing of temple doors was effected by the alternate rarefaction and condensation of air which was brought in contact with heated and cooled surfaces of altar tops. Yet the science of pneumatics played no important part in industrial progress until scarcely more than a century ago it came into general use for diving-bells, and later on it was applied by Brunel to caisson work.

The use of compressed air in America has been confined almost exclusively to mining, tunnelling, bridge building and work in a confined space for which no other power was available. The question has not been one of economy of power, but of durability of apparatus, low first cost, light weight, economy of space and general availability for the purpose. Dry, pure air delivered at a sufficient pressure by a machine which could be depended upon, has been the controlling consideration. Such a condition of things offers no stimulus in the line of fuel economy, and it is only during recent years and since the use of compressed air has been extended to work above ground, that the percentage of power delivered in proportion to that consumed has been recognized as a thing of great importance in the science.

Since the necessity of economy in the production and use of compressed air power became recognized, the question has been considered and the science developed by two

distinct classes of men, the theorists and the practical men. The theorists are the professors and engineers whose skill as mathematicians has enabled them to indulge in such an array of figures, and to produce so many cobwebs in diagrams relating to the expansion and contraction of gases, and bearing upon the intricate laws of thermodynamics, that the more practical engineers have avoided the subject as one which belonged only to specialists. The practical men have been left to themselves to make improvements, and have made slow progress because they did not possess the proper theoretical knowledge. In other words, that true combination of theory and practice which leads to the best results has been wanting among pneumatic engineers.

The whole question of compressed air economy is based upon

(1) Economy of production;

(2) Economy of use.

Transmission calls for but little consideration. This statement will doubtless surprise many who look upon the losses suffered in the use of compressed air as due largely to transmission, and no better evidence is needed of the obscurity of the science, even among engineers, than this fact. There is not a properly designed compressed air installation in operation to-day that loses over five per cent. by transmission alone. The question is altogether one of the size of pipe, and if the pipe is large enough the friction loss is a small item. It is undoubtedly true that there are places where a conduit has been laid for a certain volume of air, and where the supply has been increased without increasing the size of the conduit, the result of this being that more air is forced through the pipe than its sectional diameter will admit economically; hence the velocity of flow is increased, and as the friction is in direct proportion to the velocity, the loss of power is also increased. The largest compressed air power plant in America is that at the Chapin Mines in Michigan, where the power is generated at Quinnesec Falls, and transmitted three miles. This is not an economical plant, but the loss of pressure as shown by the

gauge is only two pounds, and this is the loss which may be laid strictly to transmission. I recently visited the Jeddo Tunnel, near Hazelton, Pa., where compressed air at sixty pounds pressure is conveyed 10,860 feet. They told me that they had tried the gauges on both ends of the line, and had found no difference whatever in pressure, but that the gauges had been sent to the shops for repairs as they were convinced that "something was wrong." The result was not changed when the gauges had been "repaired," and it was evident that this apparently perfect economy of transmission was due to the fact, that a large pipe (five and three-fourths inches in diameter) was used to convey so small a volume of air, that the velocity in the pipes produced so small a friction loss that it could not be recorded on the gauge.

A question commonly asked is, How much power is lost in using compressed air? I usually reply, fifty per cent., because a proper qualification of the question will result in figures in one case below and in the other above fifty per cent. If compressed air is produced by the best modern air compressor, and used by the best modern engine *immediately at the compressor*, the loss is only that which is suffered when using any like engine, and is confined in its greatest extent to the question of engine friction, and is only to a small degree influenced by shrinkage of volume through radiation, clearance loss, leakage, etc. In such cases the loss varies between ten and twenty-five per cent., but such cases are rare, because it would obviously be more economical to use the steam direct.

The usual conditions of compressed air use are those where the air engine is situated from 1,000 feet to several miles from the compressor. In most cases the distance is so great that the compressed air enters the engine at a temperature equal to that at which it entered the compressor. Were it possible to produce compressed air isothermally; that is, without increase of temperature during compression, the service would be economical even at low temperatures, but isothermal compression has never been realized, and the heat produced during compression (which is the exact

equivalent of the power applied) is suffered to increase the pressure, and hence to increase the resistance to compression, without a relative increase of volume. Hot air under pressure is discharged into a receiver, and the gauge indicates a pressure of (say) sixty pounds, which is equal to that recorded by the gauge 10,000 feet away, yet it is a false indication as affecting the question of power, because every cubic foot of sixty pounds air at the compressor is less in weight than an equal volume of equal pressure air at the engine, in exact proportion to the difference in temperature. The result of this is that an air engine which uses (say) 100 cubic feet of sixty pounds air per minute at the temperature of the surrounding atmosphere, really uses about 150 cubic feet of sixty pounds air at the receiver temperature. All this is very important in looking for a remedy for compressed air losses, because it points to the influence of heat upon air, and the importance of reheating compressed air.

The loss of power in common practice where compressed air is used to drive machinery in mines and tunnels, is about seventy per cent. I refer to cases where common American air compressors are used, and where the air is transmitted far enough to lose its heat of compression and is exhausted without reheating.

In the best practice, with the best air compressors, and without reheating, the loss is about sixty per cent.

These losses may be reduced to a point as low as twenty per cent. by combining the best systems of reheating with the best air compressors. In France, England and Germany there have been erected during recent years large compressed air installations. In Paris about 25,000 horsepower is transmitted over the city and is used to drive engines and for many other purposes. With a less efficient production than our American system, they have advanced beyond us in the use of compressed air. Reheating has been put into general use, while here in America the improvements have been more conspicuous in the air compressor. Prof. Kennedy, whose elaborate report on the Paris plant is accepted as an authority, uses the following words:

"Summarizing now the whole matter as regards effi

ciency, it may be said that the result of my detailed investigations is to show that the compressed air transmission system in Paris is now being carried on, on a large commercial scale, in such a fashion that a small motor four miles away from the central station can indicate in round numbers ten horse-power, for twenty horse-power at the station itself, allowing for the value of the coke used in heating the air."

Prof. Kennedy concludes his report by saying, "Nothing, indeed, can be easier (as was evident on the recent visit of the Institution of Mechanical Engineers to St. Fargeau) than to point out various weak points in the arrangements

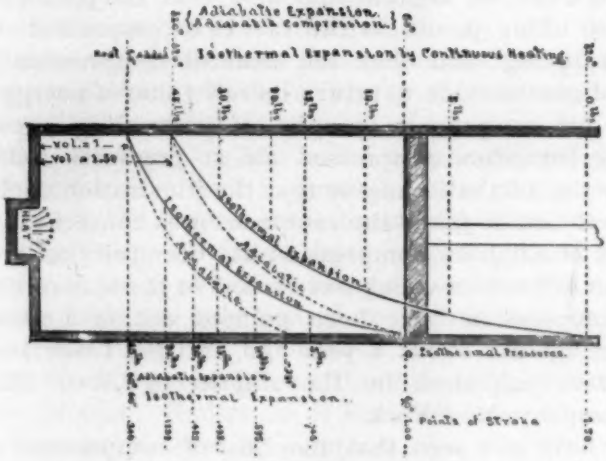


FIG. 1.

adopted." We may reasonably expect to add to this fifty per cent. efficiency attained in Paris by an installation which combines the American compound condensing Corliss air compressor with an efficient and economical reheating apparatus and Corliss or other economical engines.

The whole science of the production and use of compressed air can be best understood by a simple practical illustration.

Fig. 1 is an open cylinder which may be made to illustrate at the same time the air compressor and the air engine. The piston at the point shown is supposed to confine a volume of free air in the cylinder and at a tempera-

ture of 60°. Let it be pressed down until it reaches the point indicated by forty-five pounds at the left, and the pressure will follow the dotted line marked "Adiabatic." This is, of course, assuming that the heat, which is invariably produced by compression, is suffered to remain in the air and to influence the pressure. We here have a confined volume of compressed air at a pressure of forty-five pounds and a temperature of 320°. Let there be no absorption of heat and the piston if released will return to the starting point, the pressure following exactly the line indicated during compression and the temperature returning to 60°. In such a case we assume, of course, that the piston is frictionless. This points to the fact that compressed air is a perfect spring, and that the heat of compression when utilized can be made to return its full value of energy.

An air compressor in spite of its cooling apparatus usually furnishes compressed air at pressures following closely the adiabatic line, so that the illustration applies to a typical case so far as the compression is concerned. This subject of adiabatic compression has been fully referred to, and the difficulties which have stood in the way of isothermal compression have been pointed out in a pamphlet written by me about a year ago, entitled *Compressed Air Production*, published by the *Engineering News* Publishing Company, New York.

We have now seen that the heat of compression is not such a serious thing provided it can be utilized. The hot compressed air confined below the piston at the forty-five pound point, if transferred through pipes or otherwise to an air engine and maintained hot, will do as much work as we have just seen is possible when applied to the air compressor itself in driving the piston back to the starting point. To convey this air some distance hot, is a difficult matter, for compressed air though very slow in taking up heat, has so low a specific heat that it parts with its temperature rapidly. This loss of heat is the only serious obstacle, because, as we have seen, the friction loss in the pipe is not serious, and experiments have conclusively proved that leakage in a good system cuts no figure in the loss of

power. I have pointed out in *Compressed Air Production*, the reasons why clearance loss is of little consequence in an American air compressor. This is especially true in adiabatic compression because here what little clearance there is serves only to confine hot compressed air which acts as a spring, and which gives out a full return of power when the stroke is reversed.

As air parts with its heat rapidly, we cannot advise saving the heat during transmission by covering the pipe, so that we now suffer the loss of heat during transmission to go on, depending upon *restoring* the heat immediately at the air engine. Now this reheating is not, as some may suppose, a means by which the gain is only equal to the expenditure. Air is almost a perfect gas, and the application of heat is a direct transfer of energy to a substance which, through its elasticity, is capable of giving a full return. We burn a pound of coal under the boiler, and get only about ten per cent. back in power, because of the large loss in the stack, the loss in the exhaust, the difficulties in the way of utilizing the latent heat, etc., but when we heat compressed air, the thermal energy in the coal is stored in the air, and we are only limited in our efforts to utilize *all* of it by the reduction of pressure which takes place more rapidly than the reduction of temperature, and hence a warm exhaust. Radiation of heat between reheater and engine is also a source of some loss.

Returning to *Fig. 1*, let us imagine that the piston has been stopped at the forty-five pound point, and that this air, which, as we have seen, has a temperature of 320°, is transferred into a receiver and used at a point a mile away. The temperature will now be reduced to 60°, and if the system is well designed, we have nearly forty-five pounds pressure on the other end of the line, so that the volume of air will be reduced in size corresponding with the space underneath the lowest horizontal dotted line in the figure. This is marked "Volume 1." It is now used without reheating, to do work in an engine, and the line of reduction in pressure will now follow the lower dotted line marked "Adiabatic" until it reaches the point marked — 201°, which will represent

the temperature of the air when exhausted at atmospheric pressure. We now see that instead of getting back to the starting point the piston has only power enough to return about half-way.

If, on the other hand, heat were applied *during expansion*, the pressure would follow the line marked "Isothermal Expansion" and the piston would return to the starting point.

Another case is shown by the figure in which the air is compressed adiabatically to forty-five pounds, and heat enough is applied during expansion to maintain the temperature at 320°, until the air is exhausted at atmospheric pressure. This case illustrates the possibility of obtaining more power out of a given volume of air after compression than was expended at the compressor.

Reheating compressed air may be divided into two systems:

(1) That in which the reheating takes place in the conduit and before the air passes the valve of the engine.

(2) Reheating in the cylinder of the air engine after admission and cut-off.

The first case is the common practice, and is of value in that it saves *air volume*. It cannot increase the pressure because there is a continuous elastic air connection between the receiver at the compressor and the heater. Compressed air which leaves the receiver at a temperature of 300°, and which passes through a large conduit, losing its temperature, maintains its pressure because of this continuous elastic connection.

The reheater serves to reduce the *velocity* with which the air is drawn through the pipe, because it delivers hot air to the engine at the same pressure as though there were no reheater, and the temperature being higher, the power in each cubic foot of air remains the same though the *volume weight* is less. This valuable service performed by the reheater is limited only by the fact that air engines cannot work to advantage at temperatures over 350°; hence in a system that compresses air adiabatically to about sixty pounds pressure, and delivers it cold at a reheater, it is

possible to restore the temperature to the original point, and thus lose in power only through friction of the compressor, consumption of coal in reheater, friction in conduit, leakage, etc.

The second case is a problematical one, as thus far it has not been found practicable to reheat directly *in* the engine. The only device which seems to offer encouragement in this line is the system of internal reheating, which the writer has applied with some success, and which will be described later on. By internal reheating *directly against the piston of the air engine* an enormous advantage can be gained, and, as shown by *Fig. 1*, more power may be derived from a volume of compressed air than was originally expended at the compressor. This aditional power has been derived directly through heat acting upon the intrinsic energy which was stored in the free air before it entered the compressor.

The Paris reheater is simply a coke stove which surrounds the air pipe. It has been modified in various ways and at several places. The flue surrounds the air pipe nearly up to the steam chest of the engine, so that very little heat is lost. Radiation is also reduced to a small figure. Prof. Kennedy tells us: "The air was heated in passing through the stove up to 315° F. with a consumption of about 0·39 pounds of coke per I. H. P. per hour. As the admission temperature of the cold air was 83° only, this corresponds to an increase of about forty-two per cent. in the volume of the air and should, therefore (had the indicated efficiency remained the same), have been accompanied by a decrease of air consumption in the ratio of one divided by 1·42 or 0·70 inches. The air used in Paris is about eleven cubic feet of free air per minute per indicated horse-power. The ordinary practice in America with cold air is from fifteen to twenty-five cubic feet per minute per indicated horse-power. In Prof. Kennedy's experiments the engines were found to consume about fifteen cubic feet of air per minute per indicated horse-power without reheating.

The amount of fuel consumed during reheating is trifling. With the reheaters commonly employed it amounts to from one to two cents per horse-power per day. A more economi-

cal system of reheating will reduce these figures considerably. Prof. Kennedy says of the Paris reheaters: "It would not be difficult to design a more economical stove."

Fig. 2 illustrates a reheater in which the air is brought in contact with the fuel. The illustration is taken from a case which was put into actual service in connection with a rock drill. Immediately above the throttle valve and near the steam chest was placed an enlarged pipe fitting, in the interior of which, a little above the centre, was fixed a piece of wire gauze; above this gauze charcoal was thrown, some

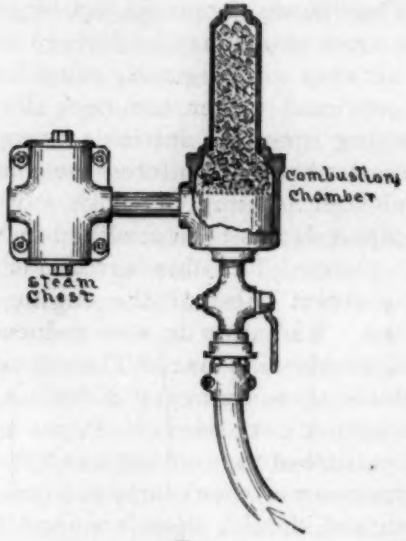


FIG. 2.

of it being in an incandescent state. The whole chamber was closed and the compressed air turned on. The air was thus brought in direct contact with the burning charcoal and was admitted to the drill cylinder extremely hot. With the consumption of a piece of charcoal an inch and a half in section and about two inches long, about two feet of hole were drilled. Instead of charcoal a substance called sestalit has been used with success, the advantage of sestalit being that it remains ignited for some length of time after the air has been shut off, and the products of combustion when discharged in a confined space are not objectionable.

The system of reheating by internal contact is theoretically the most perfect, because the full value of the heat units in the fuel are transferred to the air. The air pipe is at the same time the combustion chamber and the flue, the products of combustion adding about five per cent. to the volume of the air, in addition to the large increase through expansion by heat. Box is authority for the statement that "When oxygen and carbon combine, the volume of the carbonic acid gas formed is nearly the same as that of the oxygen consumed; when, therefore, a combustible contains carbon only, the volume of gas in the chimney is the same as

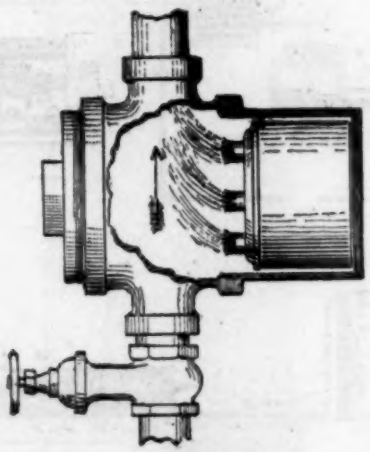


FIG. 3.

that of the air entering the fire, expanded of course to the volume due to the increased temperature, the oxygen consumed having been replaced by the same volume of carbonic acid gas. The nitrogen in the air is passive, passing through fire without chemical alteration. If the combustible contains water already formed and with which it is more or less saturated, vapor is formed from it and is added to the products of combustion."

A simple reheater is shown in *Fig. 3*.

A common lamp is placed within the air pipe, the oil being supplied to the lamp by means of a hand pump. I first applied this system to one of the pipe lines on the new

Croton Aqueduct, using a common miner's lamp placed in a four-inch pipe.

Fig. 4 illustrates an electric reheater. The air compressor is shown at *A*, compressed air being conveyed through pipe *B* to receiver *C*, thence through a conduit *D* to a pump *E*, situated (say) a mile away. In the engine room with the compressor is a dynamo *H*, which serves to light the mine. At a point near the pump a resistance coil *F* is placed in a chamber communicating directly with the compressed air. This resistance coil is made of any highly refractory substance, which resists the passage of a current to such an

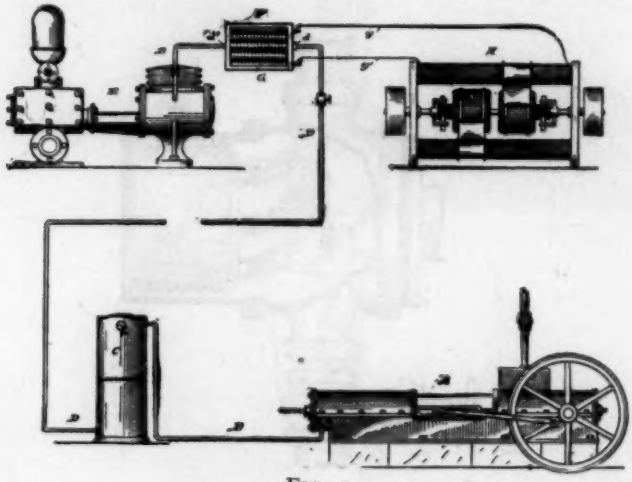


FIG. 4.

extent that the electricity is converted into heat, and the heat is thus imparted to the compressed air. Such a reheater as this has many advantages. The entire absence of combustion makes it perfectly safe for inflammable mines, and the ease with which it is applied by simply opening or closing a switch recommends it. It is also a cheap device and has been applied recently in the shape of a simple coil of wire placed in an air pipe. The conversion of electricity into heat is an economical one, it being a well-known fact that a current of any potential, when intercepted by sufficient resistance, may be entirely absorbed and returned as heat. This is accomplished unit for unit, and as

the loss in electric energy through transmission is low when compared with the shrinkage which takes place in compressed air, we here have a means by which the efficiency of the whole system may be increased by calling upon the electric wire to reheat the compressed air.

That it is theoretically possible to obtain from hot compressed air more power than was expended at the compressor, has been shown in *Fig. 1.* That this may not be confounded with perpetual motion but may be made clear, I have prepared a sketch, shown in *Fig. 5.*

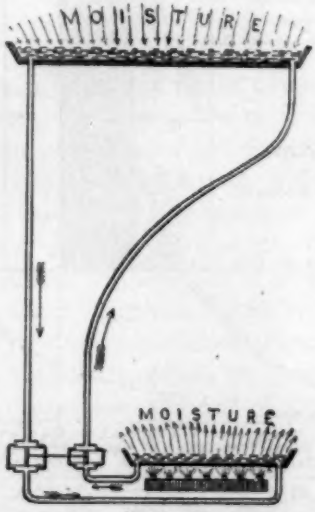


FIG. 5.

Sulphuric acid in its concentrated form, will when exposed in an open dish, absorb moisture from the atmosphere to the extent of about double its weight. A hypothetical assumption is made of a pump arranged to discharge sulphuric acid in the direction shown by the arrow to an open dish elevated (say) 100 feet. The amount of power necessary to discharge a certain quantity of sulphuric acid into this dish, is exactly equal to the power which the sulphuric acid is capable of giving out when falling back again, less the friction of the pump, leakage, etc. Now let us assume that the sulphuric acid in the open dish remained

there long enough to absorb moisture from the atmosphere until its weight has been doubled; it will thus obviously have twice the amount of power in falling back again, and if the friction and leakage losses were not too great it will be capable of driving the pump, and of returning an equivalent volume of the concentrated acid to the dish. If the same acid is used over again the moisture must be driven out, and lamps are shown in the sketch provided for this

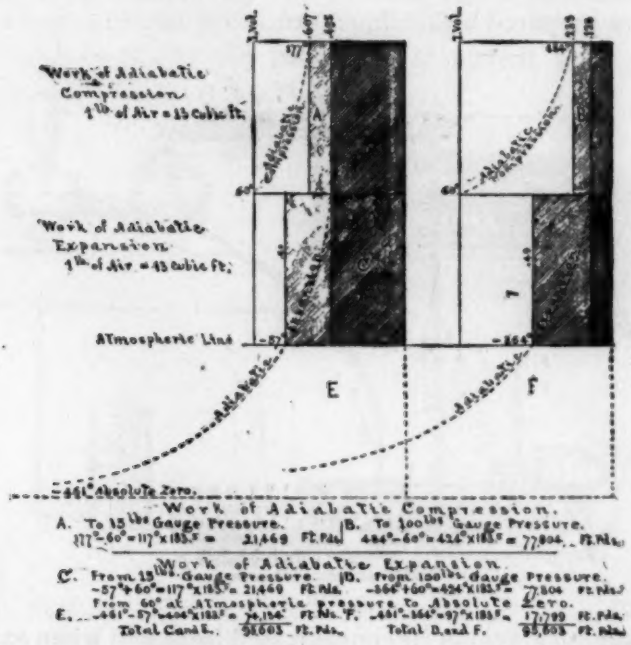

Work of Adiabatic Compression
1 lb. of Air = 13 cubic ft.
Work of Adiabatic Expansion
1 lb. of Air = 13 cubic ft.
Atmospheric Line
E
F
Adiabatic
-461° Absolute Zero.
Work of Adiabatic Compression.
A. To 15 lbs Gauge Pressure.
B. To 100 lbs Gauge Pressure.
Work of Adiabatic Expansion.
C. From 15 lbs Gauge Pressure.
D. From 100 lbs Gauge Pressure.
E. From 60° at Atmospheric pressure to Absolute Zero.
Total Cand E.
Total D and F.

FIG. 6.

purpose. The analogy between this hypothetical case of sulphuric acid and one of compressed air is, that, as with acid we may draw power from moisture which is contained in the air, so with compressed air may we draw upon the intrinsic heat energy of the atmosphere.

These thoughts suggest the advisability of defining still further what is meant by intrinsic energy. Air being a practically perfect gas it will expand or contract in volume through a definite range in proportion to its temperature.

Experiments made with air at temperatures between the freezing and the boiling points of water, have given us the ratio of contraction of volume by reduction of temperature from which the absolute zero has been determined. The absolute zero of air is about — 461° F., and is that point at which any volume of air is reduced to nothing through expansion. In other words, the air may be said to be condensed at — 461°. We have therefore a base line which limits the power contained in any body of air.

Fig. 6 is a graphic diagram drawn for the purpose of illustrating the fact that the power which is contained in any body of air at a given pressure is dependent upon its distance in temperature above the absolute zero, and that there is as much power in a pound of air at fifteen pounds gauge pressure and 60° temperature, as there is in one pound of air at 100 pounds gauge pressure and 60° temperature. One pound, or thirteen cubic feet, of air at fifteen pounds pressure and 60° temperature, is represented by the space *C*. The available power in this air is 21,469 foot-pounds. By available power is meant the amount of power which can be utilized when this air is expanded adiabatically to atmospheric pressure. The diagram shows that when such pressure is reached the temperature will be — 57° F. There still remains in this air a certain amount of *intrinsic energy* and the diagram and figures show that this energy is equal to 74,134 foot-pounds. This added to the available energy gives us 95,603 foot-pounds, as the whole energy contained in one pound of air at fifteen pounds pressure and 60° temperature.

D represents one pound of air at 100 pounds pressure and 60° temperature. Its available energy is 77,804 foot-pounds, and its intrinsic energy is 17,799 foot-pounds or the total energy is 95,603 foot-pounds, which is exactly equal to the case just cited.

These figures prove the correctness of that thermodynamic law, which states that the power of any elastic gas is in direct proportion to its height of fall. So long as the temperature is above the absolute zero, there is as much power in the same body of air when expanded adiabatically from

a moderate temperature to an extremely low one, as when expanded from a high temperature to a moderate one, and this offers to some extent a limitation to that system of reheating which increases the volume without at the same time increasing the pressure.

Fig. 7 is a diagram which illustrates a typical case in American practice, where air is admitted to a compressor at 60° and compressed adiabatically to 100 pounds pressure. It is then transmitted a sufficient distance to cool it down to 60° temperature and expanded back to atmospheric pressure, the temperature falling to — 364°. The conditions

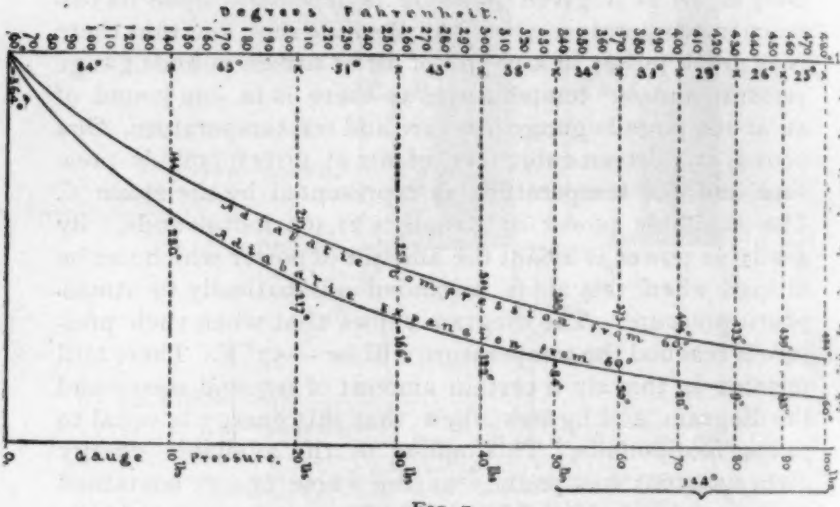


FIG. 7.

shown in the diagram are extreme and purely theoretical. In actual practice both compression and expansion are only approximately adiabatic.

Fig. 8 illustrates an economical condition of compressed air use in mines and tunnels. The power is generated electrically and is conveyed by wire to a point within a few hundred feet of the heading where a rock drill is at work. By means of an electric air compressor hot compressed air is produced adiabatically, and is expanded adiabatically in the cylinder of the drill, following closely the economical conditions illustrated and described in *Fig. 1*. Such a state

of things as this admits of an electric installation in the mine for the purpose of haulage, lighting, traction and pumping, to all of which uses electric energy has been successfully applied, and it gives us a means by which a compressed air drill may be successfully and economically operated at the heading. The air may be taken from the mine and when exhausted at the drill it serves to keep up a circulation in so confined a space as a heading, and as it is exhausted at atmospheric temperature there is no material change in the temperature of the mine. In some cases the air may be drawn through a flue from the outside, and thus through compression and expansion it will serve to ventilate the mine, as it does in the case of a compressed air installation. The economy of the system depends to its greatest

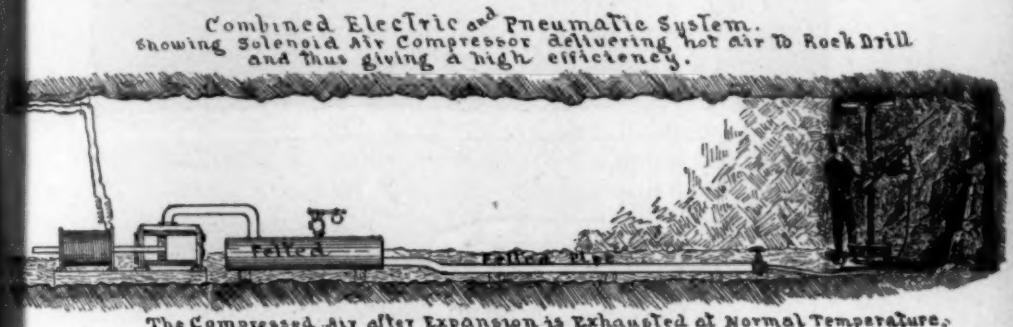

Combined Electric and Pneumatic System.
Showing Solenoid Air Compressor delivering hot air to Rock Drill
and thus giving a high efficiency.
Felted
Felted Pipe
The Compressed Air after Expansion is Exhausted at Normal Temperature.

FIG. 8.

extent upon the economy of electric production and transmission. Electrical engineers tell us that they can deliver electric energy several miles from the generating station with an efficiency of eighty per cent. If this is true its conversion into compressed air and its use as a power under the conditions shown in the illustration, may be accomplished at a very moderate reduction of efficiency, because as is plainly seen the losses commonly incurred in compressed air service do not here take place. Electric rock drills are subject to many costly limitations. Thus far they have not been successful, and it is a serious question whether or not it is possible to accomplish the drilling of rock by the percussive principle (which is the only true one), by an electric

engine which will be equal in weight, in price and efficiency to an air engine. The weight of a rock drill is one of its most conspicuous limitations, and from every basis of theory and practice a compressed air percussive engine will weigh less than half that of an electric one of the same power. An electric drill is made of copper which cannot compete in

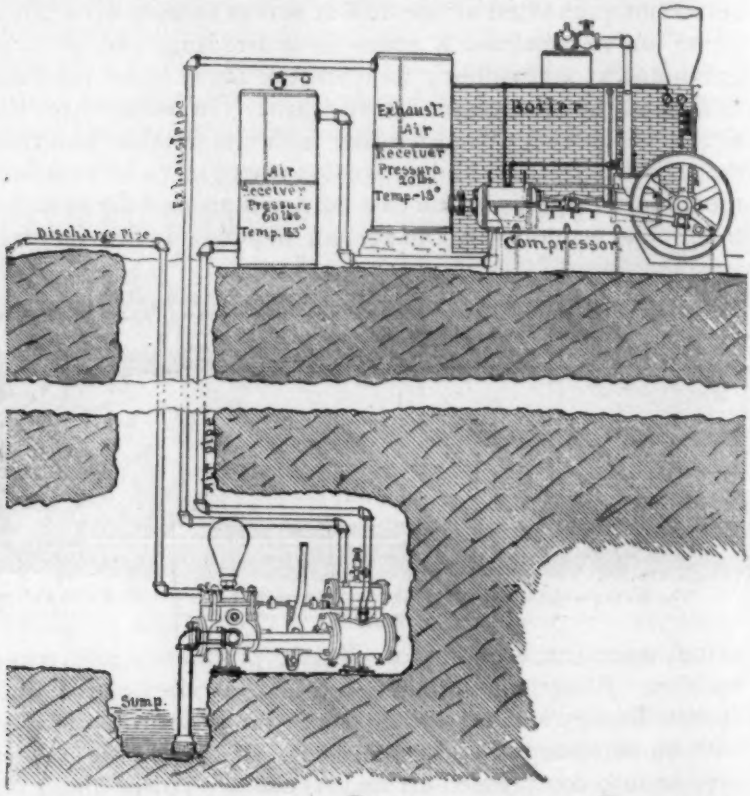


FIG. 9.

price with iron, and the durability of the apparatus is apparently in favor of the air drill. But as mines are likely to be lighted by electricity, and as there are many conditions of work favoring electric transmission for other purposes, we here have a means by which all the advantages of the air drill are maintained in an electric installation.

Fig. 9 illustrates what may be called an endless chain of

pneumatic power. An air compressor draws its supply of air from a receiver in which there is a pressure of twenty pounds. The air is compressed to sixty pounds, and is carried down a shaft and used to drive a pump. The exhaust of the pump is returned to the initial air receiver; and thus the same air is used over and over again, all of the exhaust pressure being utilized. As pumps usually exhaust at pressures from twenty to fifty pounds, a large saving is effected in this alone.

When starting, it is simply necessary to open a valve on the initial air receiver until a pressure of sixty pounds has been reached in the secondary receiver; the valve is now closed and the work goes on. The economy of this system is apparent. The heat of compression is converted into work in the pump, and a very low temperature of air is maintained. The economy of low initial temperature in air compression has been fully set forth in a diagram which I have published in *Compressed Air Production*, and a power diagram of such a system as this indicates several other economical points, notably the admission of compressed air instead of free air through the inlet valves, which serves to reduce the heat loss during compression and to equalize the resistance strains in the engine.

Fig. 10 illustrates in contracted form a complete pneumatic installation comprising boiler, air compressor, air receiver, air injector, supplementary air receiver, pipe for transmission, reheater and air engine. The reheater and air engine should be considered as situated from 1,000 feet to several miles from the compressor.

It will be observed that atmospheric air is drawn in the piston inlet tube of the compressor at 60° temperature. It is compressed adiabatically; that is, without any provision for cooling during compression, and in this way all of the power expended in the steam cylinder is converted into heat, which remains as power in the air. Perfect adiabatic compression, as previously stated, cannot be attained because of the absorption of heat by the metallic surfaces, radiation, etc. For the sake of illustration, however, the figures are given at adiabatic compression.

Now, we have seen that, if all of this heat can be utilized, it will return 100 per cent. in power, less such small items as friction, leakage, etc., and the purpose of this sketch is to call attention to a means by which at least a large part of this heat may be saved, and not wasted by radiation into the atmosphere or by absorption in water. An air injector is located between two air receivers, and the highly compressed or the highly heated air from the first receiver is admitted through the nozzle of this injector, and is thus converted into high velocity inducing free air from the atmosphere, and discharging an increased volume at a reduced pressure and temperature into a secondary

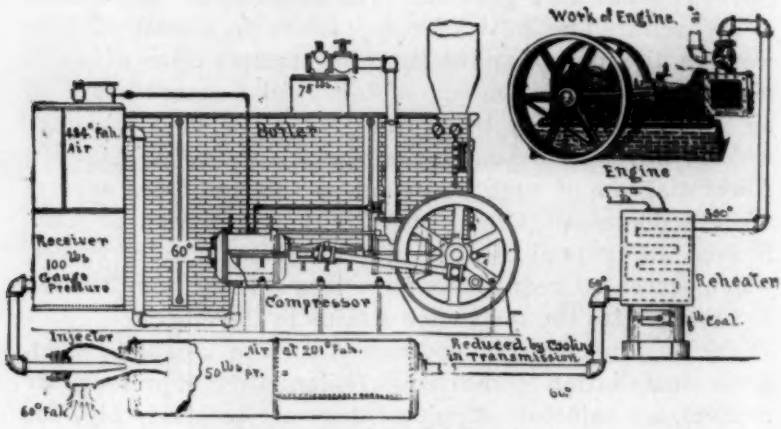


FIG. 10.

receiver. For the sake of illustration, the pressure in the first receiver is taken at 100 pounds and is reduced to fifty pounds.

This air injector has been tried with success though the experiments have not gone far enough to determine to what extent it will effect a saving in the production of pneumatic power. It has been found that with a pressure of eighty pounds in the first receiver, the injector will work discharging and inducing free air into a second receiver in which is maintained a pressure of sixty pounds. This difference of pressure may obviously be modified by the shape of the nozzle, sizes of pipes, etc., and it is probable that the

injector may be made to work at a difference between the two pressures of only ten pounds.

The principle is similar in many respects to that of the boiler feed injector about which there are so many mysteries. We know that not only is it possible to feed a boiler through an injector which takes the steam at a pressure lower than the boiler pressure, but the *exhaust injector* is a practical success. That we may exhaust steam from an engine and, by means of such exhaust, feed water to the boiler which supplies the engine with live steam, is indeed a mystery, and it is fair to assume that equally valuable and surprising results may be obtained from the induced air injector.

Mr. Green, the inventor of the Green system of ventilation, which is used on Trans-Atlantic steamers, is now conducting experiments looking toward the ventilation of the Forty-Second Street tunnel, New York, by means of air induced through an injector. His experiments have shown that one volume of air when passed through the nozzle of an injector at a pressure of five pounds, will induce thirty volumes of free air; that is, a volume efficiency of thirty to one. Mr. Green measured his air by means of a meter.

His conditions were similar to that outlined in the sketch, differing only in degree, and while it is not expected that so large a percentage of volume in free air may be induced, yet on the basis of figures alone, when compared with Mr. Green's experiments, we might expect from three to five volumes.

The velocity with which compressed air is discharged through a nozzle does not differ materially at pressure of fifteen pounds and over. The actual velocity with which compressed air at five atmospheres is discharged through a short pipe, is 658 feet per second, and at ten atmospheres the velocity is 649 feet per second. This is because high pressure air is more dense than air at low pressure, and just in proportion as the density increases does its resistance to movement increase. This is one of the limitations to the pneumatic dynamite gun. They started on about 500 pounds pressure and fell short of the mark. It appeared

that it was only necessary to increase the pressure to increase the range, but the limitations were soon discovered.

With air discharged through an injector nozzle at a velocity of 650 feet per second, it is easy to understand that free air will be induced and discharged with it into a secondary receiver. The nozzle should be constructed so as to offer the maximum amount of contact for the minimum volume of discharge, and such a nozzle has been built by Mr. Green; it takes hold of the induced air not only on the outside but also directly in the centre or core of the jet.

This is not a case where something is sought from nothing. The hot compressed air is converted into high velocity and thus the heat of compression is utilized. Were it not utilized in this way it would simply be discharged into the atmosphere by radiation, which is the usual practice in long-distance transmission in America.

Compressed air cannot be produced isothermally. In spite of the best system of injection combined with water jackets and a complicated apparatus, there will still be the heat of compression influencing pressure during compression. Compressors have been made which show cold discharge pipes and passages, and cold air in the receiver, but the largest part of this reduction in temperature has taken place *after* compression. If we cannot keep down the heat during compression, and if it be true that in keeping it down even to a reasonable extent, large complications are involved in the machinery, why not let it be produced and so simplify the apparatus, then let this *hot high pressure expanded air* be discharged through one or two injectors until its temperature has been reduced to a point *approximately what it will inevitably reach during transmission*, and thus *we have converted the heat of compression into air volume.*

The reheater shown in the sketch is little more than a common stove, the air pipes passing through the furnace. This saves *volume* of air only, it cannot increase the pressure. The engine which is driven by the compressed air should be provided with an automatic cut-off, and to insure economy it should exhaust at atmospheric pressure. It is obvious that when exhausting at atmospheric pressure

it will also exhaust at a comparatively high temperature, unless the air is first admitted at a pressure sufficiently high to admit of early cut-off and complete and economical expansion. This points to economy under some conditions by using high pressure air in an engine which works in connection with a system of reheating, and it also points to the highest economy which will be shown by that system which follows the conditions shown in the sketch, but which reheats or rather explodes the compressed air *behind the piston of the air engine after admission and cut-off.* This principle has been verified to some extent in certain oil and air engines, notably the Priestmann and Grigg, which have recently been brought to the attention of engineers.

CELLULOSE OR WOOD FIBRE.

By Prof. S. P. Sadtler.

[*A lecture delivered before the Franklin Institute, February 1, 1892.*]

The percentage composition of dry and ash-free cellulose corresponds to the formula $(C_6H_{10}O_5)_n$. It is, therefore, placed in the class of polysaccharides, to which starch and many of the gums belong. It must be understood, however, that this applies to the purified cellulose after the extraction from admixture with other associated principles. This extracting is done by exposing the moist vegetable tissue to the action of chlorine gas or of bromine water in the cold, and subsequent boiling in dilute ammonia, repeating this treatment until the alkaline solution no longer dissolves anything from the tissue or fibre. With many plants, such as cotton, flax, hemp, etc., this reaction, while requiring time and repeated action of the reagents, can be effected with thoroughness. With others such as jute, straw and compact wood the extraction is combined with greater difficulty, and when accomplished yields a product differing in important particulars. It is also often a very difficult matter to draw the line between *mixtures* and combinations

of cellulose with non-cellulose constituents of either fibres or tissues.

The following compound celluloses Cross & Bevan, who have made an especial study of this subject, consider sufficiently characterized to warrant special description under class names:

Pecto-celluloses.—Resolved by hydrolysis (with alkalies) into pectic acid and cellulose. Type—raw flax.

Ligno-celluloses.—Resolved by chlorination into chlorinated derivatives of aromatic compounds, soluble in alkalies and cellulose. Type—jute.

Adipo-celluloses.—Resolved by oxidation (with nitric acid) into derivatives similar to those from the oxidation of the fats and cellulose. Type—the cuticular tissue of leaves and fruit.

The pure cellulose obtained from cotton or linen fibre retains the microscopic features of the raw fibre and thus readily betrays its origin. It is insoluble in all simple solvents, but is first swelled and then dissolved by an ammoniacal solution of cupric hydrate. As pure cellulose is comparatively inert the reactions which would serve for its identification are few. One of them may be noted, viz: its reaction with iodine. This reaction differs from that of starch in requiring for its determination the presence of an auxiliary reagent of dehydrating power, such as sulphuric or phosphoric acid or zinc chloride. Such a solution containing iodine dissolved in potassium iodide admixed with zinc chloride, colors cellulose instantly a deep blue or violet.

Not much light on the constitution of the cellulose molecule is gained by studying the action of reagents upon it, but many very interesting and technically important derivatives have been obtained. One of the most interesting of these derivatives and of considerable technical importance is the oxycellulose, which is obtained by the action of weak oxidizing agents upon cellulose. That cotton fibre exposed too long to the influence of bleaching powder solution, or even repeatedly exposed to air and light, became weakened or "tendered," had been known for a long time before it was ascertained that this was due to the formation

of an oxycellulose, which differed in many of its properties from the original cellulose. The oxycellulose attracts the basic coloring matters from their solutions, and is dyed to full shade and fast color without previous mordanting. It also has a most remarkable attraction for vanadium compounds which it takes up from the most dilute solutions.

In many reactions, moreover, it bears much analogy to the lignin of the Ligno-celluloses.

Probably the most important of the derivatives of cellulose are the nitrates obtained by allowing strong nitric acid or a mixture of nitric and sulphuric acids to act upon cellulose. Taking the doubled formula $C_{12}H_{20}O_{10}$ for the cellulose, the highest nitro derivative formed is the hexanitrate $C_{12}H_{14}O_4(NO_3)_6$, the essential constituent of the true gun-cotton. This compound is insoluble in alcohol, ether or mixtures of both, as well as in methyl alcohol. Acetone alone dissolves it very slowly.

This most explosive variety of gun-cotton, according to Eder, is not produced by mixtures of nitre and sulphuric acid but only by using the strongest nitric and sulphuric acids, in which the cotton is immersed at a temperature not exceeding 10° C. (50° F.) for twenty-four hours. The pentanitrate $C_{12}H_{15}O_5(NO_3)_5$ is best prepared according to Eder's method by dissolving the hexanitrate or explosive gun-cotton in nitric acid at 80°–90° C. (176°–194° F.) and precipitating by concentrated sulphuric after cooling to 0° C. (32° F.). After washing the precipitate with water and then with alcohol it is dissolved in ether-alcohol and again precipitated with water. This nitrate, of which small amounts may be formed in the manufacture of explosive gun-cotton, is soluble in the mixture of ether-alcohol. The tetra and trinitrates $C_{12}H_{16}O_6(NO_3)_4$ and $C_{12}H_{17}O_7(NO_3)_3$ are generally formed together when cotton is nitrated with a more dilute nitric acid, at a higher temperature and for a much shorter time than that given for the hexanitrate. This mixture constitutes collodion pyroxyline and is soluble in ether-alcohol, acetic ether, acetic acid or methyl alcohol. The dinitrate $C_{12}H_{18}O_8(NO_3)_2$ always results as the final product of the action of the alkalies upon the higher nitrates,

and also from the action of hot, somewhat dilute nitric acid on cellulose. It is the lowest derivative attainable, a mono-nitrate having not as yet been formed.

The technical uses of these nitrated derivatives of cellulose are very important. An extremely interesting lecture was delivered in this hall a few weeks ago by Professor Munroe, of the Naval War College, of Newport, in which the characters of the explosive gun-cotton were discussed and its properties narrated. An equally interesting one might be made upon the now numerous applications of the lower nitrates, constituting as they do the bases of collodion or wet-plate photography, of the manufacture of celluloid and of pyroxyline varnishes. We will, however, pass on at present to note the chemical characters of the compound celluloses, the classification of which I have already given.

The first class, the pecto-celluloses, as the name indicates, are compounds yielding pectic acid when the cellulose is liberated from its combination. Thus, in the treatment of raw flax, the retting and bleaching processes are designed to break up this natural compound, the soluble pectic acid being washed away. Dilute alkalies effect the same result and this treatment is the one often employed in plant analysis to isolate the cellulose.

The third class, the adipo-celluloses, includes the cuticular tissue of fruits and of fibres such as cotton, straw, esparto, etc. Under the action of boiling nitric acid, these tissues are resolved into cellulose on the one hand and a series of fatty acids or products of their decomposition, suberic and adipic acids, such as are obtained from cork tissue, whence the name adipo-celluloses for the class.

In the second class, the ligno-celluloses, we have included by far the most important and interesting of the compound celluloses, viz: the different forms of woody tissue and lignified fibres, such as jute. The last-mentioned fibre indeed shows so clearly the nature of the combination between cellulose and what is termed lignin, that a study of it has thrown much light upon the characters of the whole class, and has aided chemists in getting a clear understanding of the methods for isolating cellulose from its combination in

the compact woods, which are now so largely used as a source of paper-making material.

Jute is a compound of twenty-five per cent. non-cellulose or lignin and seventy-five per cent. cellulose. The non-cellulose constituent is more readily attacked by reagents than the cellulose. Thus if the compound fibre be first boiled with a weak solution of an alkaline hydrate and then exposed to moist chlorine, the non-cellulose is attacked and on subsequent boiling with sodium sulphite solution the decomposition into cellulose and soluble non-cellulose derivatives is complete. Dilute nitric acid also attacks the non-cellulose, resolving it into soluble products and can be used to isolate the cellulose, but it attacks the latter somewhat also.

Wood consists of about two parts of cellulose in admixture with one part of lignin. Very characteristic color reactions are obtained by moistening any of these lignin-containing compounds with phenols, such as phloroglucin, and hydrochloric acid. They are also colored carmine by an alcoholic solution of pyrrol and deep yellow by solution of aniline sulphate. They take up organic dye-colors very much like the oxycellulose before referred to. Among the decomposition products of the lignin or non-cellulose have been found vanillin, coniferin and several wood-gums allied to gum arabic. Indeed a recent writer places lignin, because of its composition, amongst the class of gum resins. He has found in the products of the sulphite process for preparing wood-pulp as well as in those of the soda process, transparent resinous substances which are very similar in reaction to the arabic acid of natural gum arabic. He therefore is led to offer the following theory of these two well-known chemical wood-pulp processes. If wood is boiled under great pressures with caustic soda the lignin is decomposed. The gummy matters, resins and phenols, are dissolved and the volatile compounds, *e.g.*, terpenes, etc., escape. Cinnamic aldehyde and vanillin polymerize and coniferin is decomposed. It is well-known that sulphurous acid has a decomposing or polymerizing effect upon many groups of organic compounds. In the sulphite process, it

first decomposes lignin and then the free arabic acids decompose the sulphite of lime, hereby forming the calcium salt of the arabic acid which remains in the solution while the free sulphurous acid escapes. The author is of opinion that the sulphite process is in the main hereby explained. The terpenes and aldehydes mostly polymerise and escape, together with the other volatile aromatic compounds of the woody matter as well as the sulphurous acid, whilst the non-volatile substances, *e.g.*, the resins, are left, parts of which remain as the calcium salts of the resin acids."

The technical applications of this class, as said before, are already of enormous importance. The increasing use of wood-pulp as a paper-making material is the explanation of this. We will now take up for brief notice this most important of the cellulose industries. Wood, as before stated, contains cellulose in combination with lignin, together with mineral salts and some little coloring resin. The proportion of these constituents varies somewhat in different varieties of wood, as shown in the accompanying table from Müller.

	Birch.	Beech.	Lime.	Pine.	Poplar.
Cellulose, ...	55·52	45·47	53·09	56·99	62·77
Resin, ...	1·14	0·41	3·93	0·97	1·37
Aqueous extract, ...	2·65	2·41	3·56	1·26	2·88
Water, ...	12·48	12·57	10·10	13·87	12·10
Lignin, ...	28·21	39·14	29·32	26·91	20·88

The practical problem now is to extract the cellulose in such condition as to enable it to answer the requirements of the paper-maker, viz: strength and length of fibre, which give it felting power, and for finer papers freedom from resinous and coloring impurities, such as would prevent its use as a mixing ingredient or substitute for linen cellulose.

We divide the wood-pulp methods into the two great classes of mechanical and chemical.

In the mechanical wood-pulp process, the wood, cut into blocks, is pressed against revolving grindstones, the surface of which has been roughened by the cutting of grooves.

The wood is placed so that the revolving stone shreds or tears the fibres laterally and not transversely to the line of the fibre, while a stream of water kept flowing over the stone, washes off the fibre as rapidly as it is loosened. Even then the fibres are relatively short as compared with those obtained by the chemical processes. The pressure of the blocks of wood against the stones is maintained either by screws capable of adjustment as required, or by hydraulic pressure. The pulp as washed off the stones is passed over screens, which retain larger fragments to be ground again and allow the finer pulp to pass through and this is then farther sorted by sieving.

The quality of the mechanical pulp is improved by steaming the wood thoroughly before shredding, so that the wood being softened a longer fibre may be torn off. Such mechanical wood-pulp is made and comes into commerce under the name of "steamed pulp." The specimens shown are from the Androscoggin Pulp Company, of Brunswick, Me., and are mixed spruce and pine. The steaming of the wood is continued for eight to ten hours at a pressure of about forty pounds, and drip valves are attached to the upright boilers used, so that the wood is not soaked in hot water but exposed to the action of steam only.

Paper made from mechanical wood-pulp is very liable to become discolored by the action of air and light, the lignocelluloses being much more readily acted upon than the celluloses isolated from them. This fibre is, moreover, of very slight felting power on account of its shortness, but it is cheap and is used in large amounts for filling material, or it may be exclusively for cheap newspapers.

In the preparation of chemical wood-pulp, on the other hand, the lignin or non-cellulose constituents of the wood are decomposed and eliminated, so that a relatively pure cellulose remains, in amount varying with the process employed and the kind of wood taken. The processes that have been found applicable for this decomposition of lignin and separation of cellulose are classified as follows by Cross & Bevan, in their *Paper-making:*

VIEW OF THE CHEMICAL PROCESSES FOR DISINTEGRATING WOOD.

(1) *Aqueous alkalies.*—Hydrolysis aided by alkali directly, also indirectly by combination with products of resolution. (Watt and Burgess, 1853; Houghton, 1857.)

(2) *Solutions of alkaline sulphides.*—Hydrolysis, aided by alkaline bases directly and indirectly by combination with the products. Reversal of hydrolysis lessened by presence of reducing agent. (Jullion, 1855; Blitz, 1883; Dahl, 1884.)

(3) *Water.*—Hydrolysis, aided by acids formed from the wood. Limit of action determined by reversal of hydrolysis, *i. e.*, dehydration aided by oxidation. (Fry, 1867.)

(4) *Water, together with neutral sulphites.*—Simple hydrolysis. Products removed from sphere of action by combination with base and sulphite. Oxidation prevented by presence of sulphite. (Cross, 1880.)

(5) *Aqueous acids.*—*a.* Oxidizing and hydrolytic. Nitric acid. (Coupier and Mellier, 1852; Barre and Blendel, 1861.) Nitro-hydrochloric. (Orioli, 1865.)

b. Simply hydrolytic. Hydrochloric acid. (Bachet and Machard, 1864.)

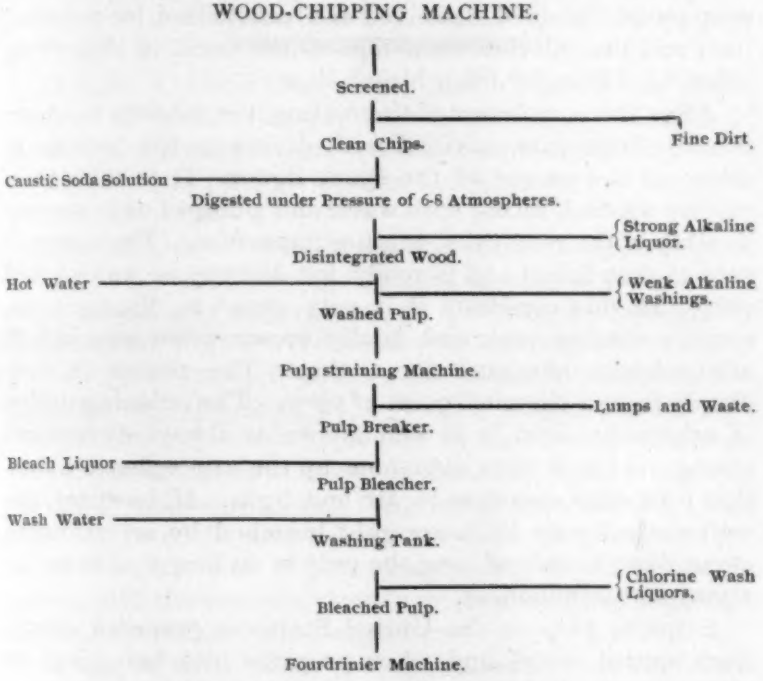
c. Reducing and hydrolytic. Sulphurous acid. (Tilghman, 1866; Pictet, 1882.)

(6) *Bisulphites.*—Hydrolysis aided primarily by sulphurous acid and secondarily by combination of products with bisulphites, also by prevention of oxidation. (Tilghman, 1866; Mitscherlich, 1874; Ekman, 1881; Franke, 1881; Graham, 1882.)

The processes in practical operation at the present time have narrowed down to those under two of these headings, viz: soda pulp processes and "sulphite," or more correctly bisulphite pulp processes.

The first of the soda processes was that of Watt & Burgess, and this, with some modifications, is still in successful use to-day. It depends, as was mentioned before, upon the fact that the lignin is decomposed by the caustic alkalies under pressure, and the products of the decomposition go into solution. Its drawbacks are that under the conditions needed to complete the disintegration of the wood, the cellulose portion itself is attacked, and hence, the yield of finished pulp is smaller than by some other processes. And when the regeneration of the soda was incompletely carried out, as was often the case, the process was an expensive one. Great improvements have been effected in this matter, however, and with the present high percentage

of recovery, the process makes a better showing. A diagram, showing in graphic form the several stages of the Burgess soda process as carried out in this city, is shown.



Of the sulphite processes mentioned in the diagram already given, that which is most generally employed in this country is the Mitscherlich, while in England the processes of Ekman and Franke, as modified by Partington, have been tried in addition. The Mitscherlich and the Franke processes use bisulphite of lime, while the Ekman process takes a bisulphite of magnesia. The sulphurous oxide, of course, is produced by the burning of sulphur or pyrites, and this gas, after being cooled, is passed into milk of lime, placed in large tanks, which are used either singly or connected in series for more complete absorption. This bisulphite liquor then acts upon the chips in closed boilers or "digesters" under a pressure of ninety pounds, for some

nine to ten hours. A longer boiling at somewhat lower pressure is also used in some cases.

Of the side-products, shown to the right in the diagram, the strong alkaline liquor is run to the evaporator to be evaporated, calcined, dissolved and causticized for renewed use; and the chlorine wash liquors are used in dissolving chloride of lime for fresh bleach liquor.

After the completion of the boiling, the mixture is blown out into large vats provided with drains in the bottom to allow of the escape of the spent liquor. It is then thoroughly washed, mixed with water and pumped onto screens to allow of the removal of chips or impurities. The screened pulp is then felted and is ready for delivery as unbleached pulp. In this condition it is very prone to discoloration, usually turning pink and finally brown when exposed to atmospheric influences for a time. The reason is very simple from a chemical point of view. The reducing action of sulphurous acid, it is well known, is always a transient change and is in time overcome by the atmospheric oxidation following exposure to air and light. If, however, the well-washed pulp is thoroughly bleached by an oxidizing agent like chloride of lime, the pulp is no longer affected by atmospheric influences.

Sulphite pulp in the United States is prepared chiefly from spruce wood, and when properly bleached gives an almost pure cellulose, white and of strong fibre.

The wood-pulp production of the United States more than trebled during the decade between 1880 and 1890, and now employs between 200 and 300 factories, of which the larger number run, of course, on mechanical wood-pulp, although the chemical wood-pulp processes are gaining ground relatively faster, and are at present coming into greater favor.

OBITUARY.

CHARLES J. SHAIN.

Charles J. Shain, for nearly half a century an active member of the Institute, and for several years a member of its Board of Managers, recently died at Atlantic City, N. J., where, for some time previous to his death, he had made his permanent home.

The subject of this sketch was born in Philadelphia, October 27, 1822. He was educated at private schools, and as a minor was apprenticed to William J. Young, the founder and head of the then principal establishment in Philadelphia engaged in the manufacture of mathematical instruments. In 1850, he formed a co-partnership with Joseph Knox (one time foreman in the Young establishment), under the firm name of Knox & Shain, manufacturers of engineering and telegraphic instruments. This firm continued in active business until the death of Mr. Knox, in 1877, and became widely and favorably known throughout the country, their instruments taking high rank in the estimation of civil engineers.

It may be of interest to record the fact that the instruments used by the late Edgar Thompson, in the first survey of the Pennsylvania Railroad, were those of Knox & Shain.

Upon the severance of this long-time connection, by the death of his associate, Mr. Shain retired to private life. His connection with the Franklin Institute dates from his election to membership, in the year 1843, and was continued uninterruptedly to the time of his death. He was elected to the Board of Managers in 1884, and served until 1887, when, on account of his removal from the city, he declined a re-election. He was warmly interested in the Institute, and contributed freely of his time and special knowledge to the furtherance of its work. He died at Atlantic City, on November 23, 1891, of Bright's disease, in his 70th year.

His unvarying courtesy and amiability greatly endeared him to his fellow-members and officers, by whom his loss is sincerely deplored.

Mr. Shain leaves a widow and two sons to survive him: Dr. Francis W. Shain, for some years surgeon in the service of the Red Star Line and at present a practising physician in Jersey City, and Chas. D. Shain, district manager for the Edison Company, of New York. W. H. W.

EUGENE H. COWLES.

Eugene H. Cowles, who died at El Paso, Tex., on April 21, 1892, at the early age of thirty-eight, had attained a world-wide recognition by the scientific world for his inventions in connection with the manufacture of aluminum. These inventions, in the origination and development of which he was assisted by his brother, Albert H. Cowles, involved in principle the application of the heating action of the electric current for the reduction of aluminum and other metals, and are too well known to need extended reference in this place. It will suffice to allude to the fact that the result of the Cowles inventions was a revolution in the aluminum industry as profound as that caused by the earlier work of Deville. The process enabled the inventors to produce the alloys of aluminum vastly more cheaply than had hitherto been possible, and at once a large demand for these products was created. To carry out their process effectively, the Messrs. Cowles were compelled to do a large amount of pioneer work, in connection with the design of dynamos of large power, the control of currents of hitherto unprecedented magnitude, the manufacture of carbon electrodes of great size, and to work out, in the face of many difficulties and discouragements, many details of operation that now seem comparatively easy, but for which at that time there were no precedents to build upon. For all this pioneer work and for the successful introduction of their process in this country and in Europe, the brothers Cowles deserve the highest praise.

The first institution of learning to take note of, and to recognize the importance of the inventions of the Cowles brothers, was the Franklin Institute. Shortly after the first public announcement of the Cowles process, an invitation was extended to the inventors to read a paper on the subject before the Institute, which was accepted by the subject of this sketch. This paper was presented at the stated meeting held January 20, 1886, and, under the title, "The Production of Aluminum and its Alloys in the Electric Furnace," appears in the impression of the *Journal* for February, 1886. It was an able and comprehensive treatment of the subject, and reflects the highest credit on its author.

The success with which the efforts of the inventors to secure the general adoption of their process was crowned, sufficiently demonstrates that their faith in its commercial and technical value was neither misplaced nor exaggerated.

The Franklin Institute, in recognition of the merits of the invention of the Cowles brothers, awarded to them, in 1886, the highest honor in its gift—the Elliott Cresson Medal—"for their invention of a new process in the metallurgical arts for the reduction of refractory substances," and recommended the award of the John Scott Legacy Medal and Premium to the inventors, "for their electric smelting furnace," which recommendation was subsequently confirmed by the Board of Directors of City Trusts.

Subsequent events demonstrated that the judgment of the Institute in estimating the value of these inventions so highly was fully justified. The late Mr. Cowles never forgot the early appreciation of his work by the Institute, and cherished the tokens of its recognition with affectionate regard.

His untimely death before he had yet reached the measure of years when those better equipped with physical endowments are in the prime of their powers for usefulness, is a loss which all friends of science will learn with sincere regret.

W. H. W.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, April 19, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Professor Henry Trimble read a paper on "Chestnut-bark Tannin." This paper gives the results of an investigation which forms the second and final part of a research to determine whether any differences exist between the tannin extracted from the wood of the tree on the one hand and the bark on the other. The results of the investigation of the tannin from the wood have already been published by Prof. Trimble in a former paper read before the Section. The results formed a subject of a brief discussion, and the paper was submitted for publication in the *Journal*.

A sample of the tannin was exhibited by the author.

A brief communication from Mr. Chas. E. Ronaldson, M.E., on "The Influence of Bottles upon Wines," was read and discussed by the Section. The same related principally to the progress made in the United States by glass manufacturers in producing glass of proper composition for the purpose named.

The Section then adjourned.

WM. C. DAY, *Secretary*.

CHESTNUT-BARK TANNIN.

By Henry Trimble.

[*Read at stated meeting of the Section, held Tuesday, April 19, 1892.*]

In the manufacture of chestnut extract the bark and wood are used together, the latter naturally exceeding the former in amount, as well as in yield of extract.

It has been thought desirable to determine if there exists any differences in the character of the tannins from these two parts of the tree, and the results of an investigation of that from the wood were published in this *Journal*, **132**, p. 303.

The material in this case was obtained from a tree thirty years old, cut in August; the bark was immediately removed, air dried and powdered.

The total tannin was found to be 7·31 per cent. The wood yielded 7·85 per cent. The other important constituents in the bark were found to be in per cent., 1·09 of resin, 3·06 of mucilage, 1·35 of glucose, 10·00 of moisture, 4·71 of ash and 45·44 of cellulose.

The tannin, as extracted by commercial ether, was much darker in color than that similarly prepared from the wood, but an equally light-colored product was obtained by first precipitating in fractions with lead acetate, and then further treating the middle and most abundant one with salt and acetic ether. The aqueous solution of this portion, after removal of lead by hydrogen sulphide, when saturated with common salt, separated a dark-colored portion which rose to the top, and was easily removed in one mass after standing twenty-four hours. The remaining light-colored solution was agitated with acetic ether, the latter separated, and, after removal of the solvent under reduced pressure, a light-colored product was obtained. This was then dissolved in water, filtered and the solvent distilled off under reduced pressure; it was then dissolved in ether, filtered and again dried in a vacuum at the temperature of a boiling water-bath.

The product was a light, almost white, porous mass of a reddish-brown shade, which was completely and readily soluble in water and the other usual solvents, and in all other respects corresponded with the chestnut-wood tannin described in the previous paper, as well as with gallotannic acid. It did not give any reaction for glucose, from which compound it was rather more easily purified than the product from the wood.

The average of two closely-agreeing combustions gave the following percentages, with which are given those from the tannin of the wood, for comparison:

	Chestnut-bark Tannin.	*Chestnut-wood Tannin.*
C,	52·42	52·11
H,	4·67	4·40
O,	42·91	43·49
	100·00	100·00

The conclusions to be drawn from this work are that the tannins from chestnut bark and wood are identical, and, although ultimate analyses show high percentages of hydrogen in both, they are believed to be identical with gallotannic acid.

In an investigation of the darker tannin precipitated from aqueous solution by salt, the following percentages were obtained:

C,	55·18
H,	4·72
O,	40·10
	100·00

This product was considered to be a mixture of the tannin with its anhydride.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, April 5, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 5, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the balance in the treasury, and presented bills for lantern slides, printing, etc., which were approved and ordered paid. The Secretary announced the death of Mr. Thomas Hockley, active member, on March 12, 1892, and upon motion the chairman appointed a committee to draft suitable resolutions for the section.

Mr. C. H. Bedell read a paper on "Dynamo and Motor Calculation," with illustrations. Referred for publication.

Mr. Herbert S. Lloyd (visitor) described, with the aid of a working model, a new method of wiring incandescent lights, so that they could be controlled by switches from any number of points, on two or three-wire systems.

Prof. Houston read a letter from Prof. Elihu Thomson, in which the latter described some interesting experiments he had been making with alternating currents of high potential. It was also stated that Prof. Thomson would probably show these and other new experiments before the Section at a future meeting.

There was an informal discussion on the trolley system of electric street car propulsion, and on the conditions under which the passage of an electric current through the body would probably be fatal to life.

Prof. Rondinella proposed to amend Sec. 1 of Art. II of the By-Laws, by striking out the word "first" and inserting in its place the word "fourth," making the section read, "The Stated meetings of the Section shall be held on the fourth Tuesday of each month at 8 P. M., except during the months of July and August." (This amendment will come up for action at the next stated meeting.)

The meeting then adjourned.

L. F. RONDINELLA. *Secretary.*

CORRESPONDENCE.

To the Committee on Publications, Franklin Institute, Philadelphia.

GENTLEMEN:—Will you kindly publish in your *Journal* a few remarks upon the article by C. B. Dudley, Ph.D., on pp. 81 and 93 of the *Journal*, current volume?

As a member of the firm of Torrey & Eaton, New York, I have given much attention to the analysis of bearing metals, having personally manufactured 1,000 tons of various alloys, and have carefully read the article by Dr. Dudley. Knowing his experience as an analyst and of his high standing as a member of the Mechanical Engineers, I was surprised to note that among the various analyses of bearing metals given, he has made several grave errors in the analysis of magnolia metal. This may work to the injury of a company which has done much to advance the interests of mechanics.

I am looking at this matter from an entirely scientific standpoint, and would not expect the *Journal* to take it up in any other way.

In the analysis of magnolia metal, Dr. Dudley has overstated one constituent part and has omitted tin (which it always contains) and other material. On the same page is given an analysis of antimonial lead, which may be correct, but not an ounce of this is ever used in magnolia metal, and the public will compare it with the magnolia analysis as given. This may work to the injury of the reputation of the makers of magnolia.

Respectfully yours, H. G. TORREY.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Brainard, F. R. *The Sexant.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Burke, M. D. *Brick for Street Pavements.* Cincinnati: Robert Clarke & Co. 1892. 8vo. Paper. Price, $1.

Church, I. P. *Notes and Examples in Mechanics.* New York: John Wiley & Sons. 1892. 8vo. Price, $2.

Duquesnay. *Résistance des Matériaux.* Paris: Gauthier-Villars. 1892. 16mo. Price, 3 francs.

Dwelshauvers-Dery. *Étude Experimentale Calorimetrique de la Machine à Vapeur.* Paris: Gauthier-Villars. 1892. 16mo. Price, 3 francs.

Gouilly, Al. *Transmission de la Force Motrice par Air Comprimé ou Raréfié.* Paris: Gauthier-Villars. 1892. 16mo. Price, 2 francs.

Merriman, M. *Text-Book on Retaining Walls and Masonry Dams.* New York: John Wiley & Sons. 1892. 8vo. Price, $2.

Ohm, G. S. *The Galvanic Circuit Investigated Mathematically.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Picon, R. V. *La Distribution de l'Électricité.* Paris: Gaulthier-Villars. 1892. 16mo. Price, 2 francs.

Plympton, G. W. *How to Become an Engineer.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Richard, Gustave. *Les Nouveaux Moteurs à Gaz et à Petrole.* Paris: Uve. Ch. Dunod. 1892. 4 vols. 8vo. Price, 75 francs.

Staley, C. and G. S. Pierson. *The Separate System of Sewerage.* New York: D. Van Nostrand Company. 1891.

Tillman, S. E. *Elementary Lessons in Heat.* New York: John Wiley & Sons. 1892. 8vo. Price, $1.50.

BOOK NOTICES.

A Manual of the Steam Engine. Part II. Design, Construction and Operation. By Robert H. Thurston, A. M., LL.D., Dr. Engineering. New York: John Wiley & Sons. 1891. Pp. xxiv, 934.

This second portion of this latest of Prof. Thurston's works is fully up to the standard of the first volume, and perhaps, from the full and able review of that portion in the *Journal*, little more need be said. The work is divided into chapters on design of the steam engine; design of valve gearing and steam distribution; regulation of the engine, governors, fly wheels and inertia effects; construction and erection; operation, care and management of engines; engine and boiler trials; specifications and contracts, and finance.

It is the last chapter that will be of most interest to engineers generally, as the author has here brought together a large amount of data not heretofore collated, and which will be interesting reading to every engineer. The blank forms used for determining costs, published by Mr. Towne in the *Transactions* of the American Society of Mechanical Engineers, are here reproduced together with the forms printed in the *Transactions* of the National Electric Light Associations.

Numerous instances of large savings from modifications of steam plants are given. Estimates are given as to the costs of large steam plants and of boilers, but it is not possible from the text to tell just what is included in the estimate. Tables follow giving the number of attendants required on vessels of different nationalities. Costs of engines and boilers under different conditions are given, which are valuable if one has the original papers at hand to determine the conditions under which the estimates are made. For instance, taking an engine from one of the tables we have a stationary non-compound engine of 56·8 I. H. P., cost $5,331 (of course meaning plant, but

not saying so), using twenty-seven pounds water per I. H. P. and 3·27 pounds coal. This is rather an odd combination of figures, but may have been right when first printed in 1883.

This is followed by some costs of construction, taking the case of a passenger locomotive, and by the divisions of the labor costs among the different departments of a manufacturing establishment. The cost of repairs is then taken up and an example given.

The costs of operation are given for a few cases, noting the difficulty generally found in getting these costs exactly. Examples are given showing the cost of small engines using gas, steam and hot air. The relation of cost values and durability, and the arithmetical rules for computing interest are explained. The questions of the efficiency of the steam boiler from the designer's and from the owner's standpoint are stated.

The next point treated of is that of lubrication, and considerable data as to the amount of oil that has been used under different conditions have been collected. The author deduces an arithmetical solution of the treatment of this portion of the subject of costs. A table gives the cost of simple and of compound engines of from 250 to 700 horse-power and tables showing the daily and yearly running expenses of engines of various kinds and under various conditions.

A rather interesting thing is the plan of a steam plant in connection with which the author says: "The 'steam plant,' so-called, thus consists of the whole arrangement of engines, boilers, and all accessories, and its design frequently involves many important questions arising from the conditions of location, and of costs at the chosen locality. In the figure, these have been studied with a view to securing the best and most convenient location of parts, actually and relatively, etc. The plant referred to consists of two return tubular boilers and two engines driving four dynamos.

The subject of electrical energy is taken up and considerable space given to the conditions under which it is used and to the data relating thereto. The last article is devoted to the transmission of power and here again considerable valuable data have been collected.

While Prof. Thurston on the title page states that the work is intended for engineers and technical schools, it can be read with profit by any one interested in steam engines, as the mathematical parts are not at all essential to a fairly complete mastery of its contents, although there are some portions, as for instance those relating to inertia effects, which are rather beyond the comprehension of one not well versed in mathematics. H. W. S.

The Zodiacal Light. By M. A. Veeder, M. D. Extracted from *Proceedings of the Rochester Academy of Science.* Vol. i.

This is one of the many attempts made to explain the mysterious phenomenon known as the Zodiacal Light. The author attributes the phenomenon to light reflected from an extension of the solar corona, consisting of meteoric particles. The paper is attractively written and the explanations are at first sight plausible, but upon closer examination they fail to impart conviction to

the reader. While the increased brightness observed during spring and autumn may be satisfactorily explained, it is not at all clear why the light should be brightest on the evenings of spring and the mornings of fall, since the spectator has practically the same standpoint on both mornings and evenings. Nor is there any reason why the phenomenon, as explained, should be seen most pronounced in the tropics. A difference of the point of observation of several thousand miles to the north or south of the equator, is so trifling that the observed diminution of the brightness of the light as the distance of the equator is increased, cannot be accounted for. In order to still further confirm the existence of meteoric matter, the author suggests that these meteors take part in conveying those electric impulses from the sun to the earth, which, according to our experience, are transmitted during periods of solar eruptions. This assertion is also open to objections. These electric disturbances, being transmitted from the sun to the earth by induction and not by conduction, a transmitting medium is not required. H. B.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1891–92.

The attendance during these sessions has been greater than ever before, with the single exception of last year, again necessitating the division of the classes into two sets to attend on different evenings because of want of room in this very inadequate building. This department of the Institute is as poorly provided as the others with facilities and suitable appliances and surroundings for the proper prosecution of its useful and valuable work. It has led for years in the system and methods of teaching mechanical drawing, and is gradually reforming the science throughout the country, and yet has been compelled to do this at a minimum of expense and in unsuitable quarters.

The benefit of a systematic and progressive course has been well demonstrated by the work of the Senior Classes this year, which is of a higher average than ever before. This work is of too technical and scientific a nature to make a popular or attractive display, but the benefit to the student of receiving a thorough course of instruction, which will be important to his future, is far greater than if the time was spent in elaborately executing, coloring and shading a few show-pieces. The time of a night school is too limited to attempt results which would greatly impress the laity, and is much better spent in teaching principles and methods and in laying a solid foundation for the future.

The corps of instructors, comprising Messrs. Clement Remington, Lucien E. Picolet, George W. Irons, George S. Cullen, H. Allen Higgins and William H. Sheahan, possesses the great advantage that its members combine a thorough theoretical knowledge of their several branches with the practical application of them in actual work, and this circumstance has much to do with the great amount of benefit, which the intelligent pupils derive during their limited attendance at this night school.

The following pupils are entitled to Honorable Mention :

In the Junior Classes.

Arthur Bentley,
G. W. Hassellund,
James H. Leicht,
Henry J. Nelson,
A. F. Abronski,
William F. Troost,
Milton B. Stout,
T. F. Kelly.

In the Intermediate Classes.

Malcolm Lovett,
Howard R. Lamborn,
Austin Riegner,
James Marshall,
Samuel G. Barnard,
Bert. Bilhartz,
Eric Ostram,
N. Battle,
A. Martin Devoe,
Christian Hagenlocher.

In the Senior Classes.

Walter Hensel,
William Saile,
Bruce Ford,
Charles Rowe,
Abraham P. Weckerley,
William H. Simmons,
Joseph Royal,
William T. Westbrook, Jr.

In the Architectural Class.

George W. Raynor,
Charles P. Jarden,
Lewis C. Butler,
George H. Robinson,
Thomas Noble.

In the Free-Hand Class.

Robert F. Scheicher,
George T. Blaisse, Jr.,
Max L. Kohl,
Walter L. Allen,
Godfrey Semper.

The following pupils are awarded scholarships from the B. H. Bartol Fund, entitling them to tickets for the next term, beginning September 20, 1892 :

Walter Hensel,
William Saile,
George W. Raynor,
Malcolm Lovett,
Bert. Bilhartz,
Arthur Bentley,
A. F. Abronski,
William F. Troost.

The following pupils, having attended four terms and completed satisfactorily a full course, are awarded certificates :

Henry Aichele,
Edward C. Aitken,
Walter L. Allen,
Franklin W. Biedert,
George T. Blaisse, Jr.,
Julius Block,
Frederick Buehler,
Clifford I. Hewitt,
Joseph M. Hewlett,
George Lutner,
Alva S. Mackenzie,
Charles McLoughry,
John Rigling,
Charles Rowe,

Charles F. Cochrane,
George T. Coleman,
William S. Cooper,
Frank J. Crowne,
Lorenzo C. Dilks,
Jackson Dunlap, Jr.,
Henry B. Etter,
Herman Hammer,
Walter Hensel,
Andrew Sauer,
Godfrey Semper,
William H. Simmons,
George W. Todd,
Richard H. Trimble.
Paul G. Webb,
Allen Wilson,
Thomas M. Worn.

The next term will begin September 20, 1892, when endeavor will be made to maintain the progressive spirit of this department of the Institute.

WILLIAM H. THORNE, *Director*.

Franklin Institute.

[*Proceedings of the stated meeting, held April 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 20, 1892.

Mr. G. MORGAN ELDRIDGE, Chairman *pro tem.*

Present, forty-six members and five visitors.

Additions to membership since last report, eight.

The Secretary reported the death of Mr. Wm. A. Cheyney, auditor of the Institute, and moved the appointment of a committee to prepare a suitable memorial of the deceased. Carried.

Mr. E. H. Outerbridge, of New York, gave a description of a new article of manufacture, called "pantasote" leather, designed principally to serve as a substitute for leather, and especially for the more costly varieties of leather employed for upholstery, wall decorations, travelling bags, etc. The speaker illustrated his remarks by the exhibition of a series of lantern slides showing the process of manufacture, and of an interesting suite of samples of the finished products.

Mr. Thomas P. Conard presented a description, with lantern projections, of the Shay geared locomotive.

Mr. T. F. Cook, of Tacoma, Washington, followed with a description of a new method of transportation recently invented by him. The inventor employs an overhead system, the permanent way consisting of a single line of columns carrying an upper and lower girder. The invention consists further in an arrangement of horizontal pulleys which are carried on the lower girder, adapted to be driven by any suitable motive-power and by which motion is communicated to the cars. The latter are arranged to travel in opposite directions on the two sides of the elevated structure.

The Secretary read his monthly report.

Adjourned.

WM. H. WAHL, *Secretary*.